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THE ORIGIN OF LAND PLANTS[1]

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The problem of how the existing vegetation of the earth has come into being is one of perennial interest to the botanist, and I have chosen as my subject some of the conclusions to which botanists have come as to the history of the plant life which now occupies so large a part of the earth's surface.

The evolution of the plant kingdom always has had for me a special fascination, and since my first serious botanical studies nearly fifty years ago, the subject has occupied a prominent place in my scientific work. Not, perhaps, a particularly practical subject, as ordinarily understood, and no doubt some of my audience may think it a waste of time to have devoted so large a part of one's life to such investigations.

"What use is it all?" one may ask, and the answer must depend on one's outlook on life.

I might reply that it has furnished me a livelihood—that I have been well paid for doing what I most wanted to do. This might be given as a "practical" result of my activities. I am afraid, however, that I have even encouraged some of my students to go ahead in similar unpractical lines of research, hoping that they might have some of the same satisfaction in their life work that I have found. If I have succeeded in some degree in this, I feel that I have as truly performed a service as if I had merely equipped them to go out into the world and fight for money and what it brings.

The pursuit of science for the love of it, and not primarily for the material rewards it may bring, has results that no money can purchase. Such a love of

[1] Address of the president of the Pacific Division of the American Association for the Advancement of Science, Eugene, Oregon, June 20, 1930.

science may well be put by the side of the other arts, music, literature or painting—those things which we feel must have a place in the life of every truly civilized being. Having these resources, one need not be afraid of one's own company, and is independent of the multiform devices for killing time which at the present day seem indispensable to so large a part of mankind.

If we glance at the plants about us, we soon realize that a very large majority live on land, the number of aquatic species being relatively small. Of the land plants the major part are the familiar flowering plants. Next in number are the many fungi, including a host of parasitic forms, rusts, mildews, etc., with which the farmer and gardener are only too well acquainted. These, however, I hardly feel competent to discuss. Since there is abundant evidence that the primitive plants were aquatics, the botanist has to meet the problem as to the factors concerned in the migration of the aquatic ancestors of the existing land plants to their present terrestrial environment, and the extraordinary evolution of new forms which has accompanied this radical change of life on land.

If all the plants, from the earliest times to the present, had left fossil remains throughout the successive geological ages, the story of the evolution of the plant kingdom would be a comparatively simple matter; but, unfortunately, the fossil record is extremely imperfect, especially as regards the more primitive plants, which are, for the most part, too perishable to have left recognizable fossil remains. Where more resistant structures are present, such as the lime or flint incrustations of some algae, or the woody tissues of the so-called "vascular" plants, like ferns and many flowering plants, these have often been preserved very perfectly, either as impressions, or less commonly as actual petrifactions, like fossil wood, where one may make thin sections for microscopic study which sometimes show the cellular structure almost as perfectly as if made from living tissue.

From such fossil remains much has been learned about the early history of many important groups of plants, and we may hope for much more assistance from further discoveries by students of fossil plants in deciphering the story of plant evolution.

Owing to the incompleteness of the fossil record, we must have recourse to a very thorough comparative study of the living plants in our endeavors to trace their relationships. If we compare any two plants, we shall find a greater or lesser degree of correspondence in their structure, and from the degree of similarity between them we assume an indication, to a great extent, of the degree of genetic relationship. This comparative morphology must include not only the adult structure, but also the development of the organs of the plant from their earliest stages. Such study may embrace the whole life history of the plant from the germ-cell, or egg, to its mature form. Such a study of the development of the individual we call ontogeny, and such ontogenetic studies are of great importance in the establishment of a natural system of classification, as the developing embryo repeats, to some extent, the history of the group to which it belongs—or its phylogeny.

While comparative morphology is probably the most important factor in determining relationships, it is by no means infallible, and one has to exercise great caution in drawing one's conclusions. This is especially true where certain superficial organs are concerned. Thus the leaves of some seaweeds, mosses and flowering plants have a marked similarity in form and function, but we are certain that they are independent developments in three entirely unrelated plant types. Such organs have been called "analogous" but perhaps a better term is the more recent one, "homoplastic" as opposed to "homologous" organs, which latter are assumed to be genetically related. It is often difficult, however, to decide with certainty whether certain structures are really homologous or merely homoplastic.

Geologists tell us that in the earliest periods of the earth's history the seas were much less salt than at present, and that the first organisms probably lived in fresh water. Some of the simplest living things, like certain Protozoa and simple Algae, may have persisted to the present, little changed from these remote ancestors, since they are perfectly adapted to their fresh-water environment, which has not altered materially from the earliest times. It is, therefore, among such relicts of ancient life that we must look for the nearest relatives of the ancestors of the modern vegetation.

The term alga is usually given to all the plants below the mosses which possess the characteristic green pigment chlorophyll. Several independent classes of algae are recognized by the most recent students of the algae, most of these classes having, in addition to chlorophyll, other pigments. Two of these classes, the brown algae and the red algae, the former including the giant kelps of the Pacific Coast, are with few exceptions inhabitants of salt water. It is these highly specialized forms that mark the culmination of the algae, and at the present time they are the dominant plants of the ocean and have evidently best solved the problem of life in salt

water; to their peculiar environment are doubtless due their most marked characteristics. There is little reason to suppose that any of the land plants have arisen from these seaweeds.

The green algae, on the other hand, probably represent the remnants of the primordial fresh-water vegetation, which has persisted with little change to the present time. It is from forms related to these primitive green algae that there is a good reason to believe the first land plants are descended. One of these classes, the Chlorophyceae, have the chlorophyll unmixed with other pigments, and probably represent the nearest approach to the lower land plants, since the latter have much the same cell structure, including pure-green chromatophores, and with relatively few exceptions are dependent on fresh water for their existence. We may assume that the land plants, now the predominant type, are descended not from the large complex seaweeds but from much simpler fresh-water green algae. One order of the Chlorophyceae, the Ulothricales, show approximately, at least, what may have been the course of evolution in the ancestors of the earliest land plants.

Many algae are unicellular organisms, and sometimes are capable of locomotion closely resembling some of the simplest animals, Protozoa; but they differ from these animal cells in the presence of chlorophyll, which is associated with the power of utilizing the energy of sunlight for the manufacture of organic compounds, *e.g.*, starch and sugar from CO_2 and water. This power of photosynthesis is the essential character of all green plants.

Starting with this free-swimming green cell, the first step in the development of the plant-body is the loss of motility and the investment of the cell with a definite membrane, or cell wall. By repeated division in a single plane such a cell may give rise to a row of similar cells—a filament. Sometimes the contents of a cell may escape, as a naked free-swimming "zoospore"—or several zoospores may be formed from the cell contents. These later settle down, develop a cell wall and grow into a new filament.

This reversion of the reproductive cells to the motile condition is a feature which is retained even in some of the seed-plants, and is perhaps the strongest evidence of the aquatic origin of the land plants.

The simplest type of a multicellular plant is the simple filament, or cell-row. Should divisions occur in two planes, a cell-plate results, and if in three planes a solid plant body, which may assume various forms, and in such large algae as many red and brown seaweeds may reach a size and complexity rivaled only by some of the higher land plants. No fresh-water algae show anything comparable to these salt-water giants.

Unlike the sea with its constant water level, where no seaweeds are exposed to prolonged drying up, most bodies of fresh water are more or less subject to marked changes of level as well as to much greater range of temperature than prevails in the ocean, while shallow ponds and streams are often completely dried up for long periods. We find, therefore, that most fresh-water algae have developed means of surviving periods of stress due to cold or drought. Some can exist with a minimum water supply and survive long periods of complete desiccation. The little unicellular plant, Protococcus (to use the old name), which forms dark-green films on shady walls, old flower-pots, etc., may be cited as an example. A few green algae may even become true land plants, developing delicate roots which penetrate moist soil and absorb water to replace that lost by evaporation. The curious little *Botrydium* is an instance of such a terrestrial alga. However, the limitations of such a simple form are obvious, and so far as I know, none of the algae have developed a really successful land plant.

The problem of surviving cold and drought has been solved by many green algae in quite a different fashion. In addition to reproduction by simple cell division and growth, special reproductive cells, known as gametes, are developed. The gametes are sexual cells—that is, the fusion of two of them is necessary for their further development. This fusion cell, the zygote, in most cases, develops a heavy cell-wall and forms a "resting-spore" capable of resisting cold and drought, which would be speedily fatal to the parent plant. When conditions are favorable the zygote germinates, the contents usually divide into several cells which escape as free-swimming zoospores, each of which develops into a new plant.

The gametes may be alike, but in most cases there is a differentiation into large female gametes or eggs, and much smaller males, or sperms, the latter being always actively motile, while the female gamete is usually non-motile, and is retained in the mother-cell (oogonium), where it is fertilized by the active sperm.

Although it is generally assumed that the first land plants were derived from some fresh-water green algae, it must be admitted that at present we know of no forms which satisfactorily bridge the gap between the algae and the simplest land plants—the so-called archegoniates.

Of the algae, the genus *Coleochaete* shows the nearest approach to the archegoniates in the development of the zygote, which enlarges greatly after

fertilization, and on germination produces a much greater number of spores than any other green alga. This is obviously a great advantage. However, the differences in the development of the reproductive organs and the zygote, which develops zoospores on germination, are too great to indicate any direct relationship between Coleochaete and any known archegoniate.

The first invasion of the land by the algal ancestors of the higher plants must be regarded as perhaps the most momentous event in the history of the plant kingdom.

In the comparatively uniform environment of aquatic life there is much less scope for variation and selection to operate; but once established on land, surrounded by air instead of water, the fundamental growth factors—moisture, temperature, light and gravitation—become far less stable and the range of variation is evidently greatly increased, with a correspondingly enlarged field for the operation of natural selection. The results we see in the enormously greater range of structure in terrestrial as compared with aquatic organisms, both plant and animal.

When the plant exchanges its aquatic habitat for life on land it must undergo radical changes in structure. First in importance is the solution of the water problem. The submersed aquatic, surrounded by water, has no need for special organs for absorbing water, which is taken in at all parts of the surface, nor is there need for protection against loss of water by evaporation. The land plant, on the other hand, must be able to extract water from the soil, both for obtaining food and for making good the loss of water by evaporation into the air.

We find, therefore, that the typical land plants develop special organs, roots, for water absorption, and the surface cells of the stem and leaves have their outer walls more or less perfectly water-proof, and thus check evaporation. It is true that some of the lower land plants, such as many mosses and lichens, and even some ferns, can absorb water directly by their surface cells—very much as an alga does—but such plants dry up completely and remain dormant in dry air.

A submersed plant—whether alga or such a flowering plant as a pond-weed—is buoyed up by the dense medium in which it is suspended. Taken from the water, it collapses completely. The land plant must develop special supporting or "mechanical" tissues to overcome the force of gravity, or else lie prone on the ground, as we see some liverworts, among the most primitive of the land plants, and in this respect they recall their kinship with the algae.

With the increasing size of the land plants, in addition to the purely supporting or skeletal tissues, there has been developed a very complete system of conducting tissues through which water and the substances dissolved in it are transported through the plant. The woody bundles extending through the root and stem and the elaborate network of veins in the leaves serve both for giving firmness to the organs and as routes for water transport.

Since atmospheric conditions vary greatly as to temperature and moisture, land plants have had to adjust themselves to such extreme conditions as those of the saturated equatorial forest, the burning desert and frozen Arctic tundra. The water needs of a banana growing in the jungles of Borneo are very different from those of a cactus in the Colorado Desert or a dwarf willow in northern Alaska, and the temperature requirements are equally diverse. The banana, with its high water demand, is very limited as to its tolerance of temperature changes, while the willow, able to exist with a very small amount of water, can endure a range of 150° F. or perhaps more—a condition quite inconceivable for any truly aquatic plant.

All the typical land plants, *i.e.*, mosses, ferns and flowering plants, have much in common, and their reproduction is essentially the same. The egg-cell, when fertilized, instead of developing a resting-spore, as it does in the green algae, at once begins to grow and divide, so that a multicellular embryo results. Hence the name embryophyte has been proposed to include all these higher plants.

Some of the lower moss-like plants, the liverworts, probably resemble pretty closely the first land plants. These are small plants of very simple structure, lying flat on the ground, to which they are fastened by delicate roots. Structurally some of these liverworts are less complex than many algae, being composed of almost perfectly uniform cells. The green algae which seem to show the greatest resemblance to the liverworts are the Ulothricales, already referred to. Among the liverworts, one order, the Anthocerotales, closely resembles the Ulothricales in usually having but a single chromatophore in the cell—a condition found in many green algae.

A few liverworts are true water plants, and the life history of one of these suggests what may have been the transition from the aquatic environment to life on land. This liverwort, *Ricciocarpus*, usually is a floating aquatic. If, however, the water dries up, the plant settles on the mud and grows more vigorously than it does in the floating condition. Roots are developed, and the form of the plant becomes quite altered. It suggests that in similar

fashion the algal ancestors of the land plants, stranded by the evaporation of the water, may have developed roots as the result of the contact stimulus of the solid earth, and thus would be able to prolong their growing period. It is conceivable that in some such manner was inaugurated the line of land plants which was destined to become the dominant type of the future.

The essentially amphibious nature of all the more primitive land plants is shown by their dependence on free water for fertilization. In all these the reproductive organs are very characteristic structures. If we examine these in a liverwort, we find the egg-cell contained in a flask-shaped structure, the archegonium. Since this archegonium is very much the same in the mosses, ferns and even in some of the lower seed plants—these have been called archegoniates. The male gametes are also borne in multicellular organs, antheridia, but these are much less uniform than the archegonia. However, in all these forms, the male gametes or sperms are free-swimming, ciliated cells, like those of the green algae, and in order that they may function, free water is necessary. Only when they are covered with water can the reproductive organs open and permit the sperm to escape and penetrate the open neck of the archegonium, and thus reach the egg-cell.

The embryo resulting from the fertilized egg develops into a structure very different from the plant which bears the gametes, and which is therefore called the gametophyte or sexual plant. The one produced from the embryo does not become free, but remains attached to the gametophyte upon which it lives as a parasite. Sooner or later a large part of the inner tissue of the embryo develops into special reproductive "sporogenous" cells, each one of which gives rise by division to a group of four spores. The fully grown embryo, therefore, is the non-sexual or neutral plant, or sporophyte.

In the process of fertilization there is a fusion of the nuclei of the sperm and egg, and the fusion cell, or zygote, has twice as many chromosomes as the gametes. The chromosomes are those remarkable constituents of the nuclei, the supposed bearers of hereditary characters. The nuclei of the gametes are said to be haploid, while the zygote nucleus, with the double number of chromosomes, is diploid. In all embryophytes, the diploid character of the cells of the sporophyte persists until the first division of the spore mother-cell, when by a peculiar type of nuclear division—the reduction division, or meiosis—the haploid number is restored, and the gametes developed from the germinating spores have haploid nuclei.

This alternation of the sexual with the non-sexual or neutral phase, produced as the result of fertilization, characterizes all embryophytes.

Of these, the forms which most nearly resemble the algae are some of the liverworts and the gametophytes of some of the ferns, and there is no great difficulty in comparing these with algae; but when we consider the reproduction, the resemblances are not so obvious. The complex, multicellular archegonia and antheridia are very different from the usually unicellular organs of the green algae. It is true that in some of the algae—especially the brown algae, the cells containing the gametes are massed in groups of definite form, known as gametangia, and it has been suggested that possibly from similar gametangia in some green algae the archegonium and antheridium of the embryophytes have been derived. This, however, is only a guess.

The more critically the archegoniates are studied, the more evident it becomes that the living forms are remnants of a number of independent lines of development whose relationships with each other are to say the least uncertain. Two main groups are generally recognized: the bryophytes—mosses in a broad sense; and pteridophytes, of which the ferns are the typical representatives. This division is based upon the relative importance of gametophyte and sporophyte—the former predominant in the bryophytes, the latter in the pteridophytes. This classification, however, can hardly be accepted as an entirely scientific one.

While the gametophyte of many liverworts much resembles in appearance some of the algae, there are many others, and especially true mosses, in which the gametophyte may develop into a plant of relatively large size, in extreme cases forming leafy shoots a foot or more in length with specialized tissues for support and water conduction, suggesting the structures of the sporophyte in the so-called vascular plants. The root system, however, is deficient, and mosses depend largely upon the direct absorption of water through the leaves, behaving much as an alga would do.

The apparent inability of the gametophyte to develop adequate roots perhaps accounts for its failure to reach dimensions at all comparable to those of the higher plants, and in none of the larger ones are the skeletal tissues sufficient to enable them to maintain a truly upright position.

The gametophyte of the archegoniates is the descendant of some strictly aquatic plant, and it is not unlikely that there are limits beyond which such a type can not progress. The higher mosses, which represent the most perfect development of these

originally aquatic organisms, can not be said to have quite satisfactorily solved the problem of a plant perfectly adapted to life on land.

The further evolution of the land plants is mainly bound up with the neutral generations, the sporophyte. The origin of this we believe is to be found in the zygote or resting-spore of some green algae. This zygote may be said to represent a terrestrial phase of the alga—a condition fitted to survive drought and thus carry the plant over from one growing period to another. The fact that the zygote, the equivalent of the sporophyte of a liverwort or fern, is from the very first a structure fitted for life outside the water must be borne in mind in following the further history of the higher plants.

In those algae which are assumed to be the nearest relatives of the archegoniates, the zygote on germination produces several (usually motile) spores, each of which gives rise to a new plant—an evident advantage over such forms as produce but a single plant from the zygote. In Coleochaete—already referred to—the increase in size of the zygote, subsequent to fertilization, and its development into a globular multicellular body, which to a certain extent resembles the young embryo of some of the archegoniates, have suggested a possible relationship between them. While it is highly improbable that there is any direct relationship, it is pretty certain that the sporophyte of the first archegoniates must have been derived from a structure not very different from that found in Coleochaete.

A study of the development of the sporophyte of the bryophytes shows the general trend of evolution leading to the higher so-called vascular plants. The evidence, however, is much too fragmentary to permit of more than general conjectures as to what were the ancestors of the pteridophytes.

The simplest known sporophyte is that of a liverwort, *Riccia*. The embryo becomes a globular body, all of whose cells, except an imperfect superficial layer, produce spores. In most liverworts, however, the embryo is divided into an upper sporogenous region, and a basal sterile region which later forms the foot, and a more or less conspicuous stalk connecting the foot and the sporogenous region, which becomes a capsule containing the spores. The foot penetrates the surrounding tissue of the gametophyte, from which it draws the water and food materials for the further growth of the sporophyte, which thus lives as a parasite upon the parent gametophyte.

In none of the true liverworts does the sporophyte attain any considerable degree of independence, but serves merely as an organ for spore production.

In the true mosses the sporophyte becomes much more important, and spore production is to a considerable extent subordinated to the vegetative life of the sporophyte. The growth of the sporophyte may continue for a long time before any sporogenous tissue is apparent, and the amount of this is small compared to the sterile tissue. Some of the latter develops chlorophyll, which enables the plant to utilize the CO_2 of the atmosphere and is therefore quite independent of the gametophyte for its organic food, although it still obtains water and mineral substances through the foot, and never becomes entirely independent. A well-developed conducting tissue may also be formed, and a very elaborate mechanism for the dispersal of the spores. These highly differentiated structures indicate that the true mosses form a very specialized class with little direct connection with any other plants.

The very early history of the fern embryo is quite like that of the simpler liverworts, but very soon a radical difference may be noted. Instead of the globular or cylindrical form of the liverwort sporophyte, terminating in a single spore-capsule, the fern embryo at a very early stage shows the development of special organs. A large foot is present, but instead of the spore capsule two prominent outgrowths appear, one of which grows upward and soon appears as a fan-shaped green leaf, while the other, bending down, is a true root, which fastens the young sporophyte to the ground and thus connects it directly with the water-supply. With the leaf, a special organ for photosynthesis, and the roots, furnishing water, the sporophyte for the first time becomes an independent plant. A definite stem apex is established and new leaves and roots continue to form, and it may reach a large size and live for many years.

During the early stages of development, the sporophyte receives nourishment from the gametophyte through the foot, exactly as in the liverworts; but with the establishment of the roots, the gametophyte dies, leaving the sporophyte established as an independent plant.

The production of spores is often delayed for many years, the sporophyte increasing in size and developing a complicated system of organs and tissues. Of the latter the most notable is the elaborate system of conducting tissues—the "fibro-vascular" bundles, a feature of all the higher or vascular plants. In the common ferns the spores are contained in special capsules—sporangia—which are borne upon the lower surface of the leaves. The form and position of the sporangia are important factors in the classification of the pteridophytes.

Of special importance in connection with the

origin of the pteridophytes is the very peculiar order Anthocerotales, or horned liverworts, already referred to, and usually considered to be true liverworts. They differ so much from these, however, that their separation, as a distinct class, seems warranted. Of all the bryophytes, the gametophyte of the Anthocerotales, with its very simple structure and alga-like chromatophores, most nearly resembles the green algae from which it is assumed the archegoniates are descended. On the other hand, the gametophyte and reproductive organs show some striking similarities to the lower pteridophytes. We might perhaps say that in a sense the Anthocerotes represent a synthetic type, allied on the one hand to the green algae, on the other to several distinct lines of bryophytes and pteridophytes.

While the gametophyte is so simple in structure, in which it agrees with some of the more primitive ferns, the sporophyte may show a long-continued growth, and in exceptional cases may attain practical independence. In the genus *Anthoceros* the sporophyte is a slender cylindrical body which may reach a length of ten centimeters or occasionally even more. At the base is a large bulbous foot, and above the foot is a zone of actively growing tissue to which the elongation of the growing sporophyte is due. In the most highly developed cases the foot becomes much enlarged, and possibly may come into direct contact with the earth. As in the true mosses, there is a great reduction in the amount of sporogenous tissue, outside of which is a thick mass of green cells, active in photosynthesis, and as in the higher plants, stomata, or breathing pores, occur in the epidermis. Occupying the axis is a strand of elongated cells which in exceptional cases may be fairly described as a primitive vascular bundle—in short the sporophyte in *Anthoceros* may very fairly be compared with that of the most primitive pteridophytes.

In speculating upon a possible connection of the Anthocerotes with the origin of the pteridophytes, it is noteworthy that among the oldest fossil remains of land plants certain extremely simple vascular plants, the Rhyniaceae, from the lower Devonian formations of Scotland, were in structure extraordinarily like some large sporophytes of *Anthoceros*.

In the evolution of the sporophyte of the archegoniates, the most significant fact is the progressive reduction of the spore product and the increasing importance of the sporophyte as a whole, compared with the gametophyte. In the true liverworts the life of the sporophyte is brief, and its exclusive function is the production of spores. In the mosses and Anthocerotaceae, the growing period of the sporophyte is greatly prolonged on account of the production of green tissue which enables it to make its own food, but it is still dependent on the gametophyte for water, as it does not develop a root. The sporogenous tissue is greatly reduced in amount. Finally, in the ferns, by the development of a root which gets its water-supply directly from the earth, the sporophyte becomes a truly independent plant, in which the spore-function is more or less incidental.

The increasing importance of the sporophyte in the life cycle of the plant is thus bound up with transformation of potentially sporogenous tissue into sterile or vegetative tissue. The significance of this progressive sterilization of sporogenous tissue as a factor in the history of the land plants has been treated at length by the distinguished British botanist, Professor F. O. Bower.

Fossil Record

When the first land plants appeared we do not know. The earliest known fossil records are in the Devonian rocks, but these are of vascular plants related to some living forms, and it is evident that they must have had a long ancestry of simpler forms behind them.

Mosses and liverworts are too perishable to have left fossil traces, except under very unusual conditions, and fossils of these, even in more recent formations, are very scanty and fragmentary, and throw little light upon their early history.

Of the vascular plants, however, including ferns, club-mosses and other existing types, there are abundant fossils, extending from the lower Devonian formations to the present. These fossils include not only impressions of stems, leaves and fructifications, but in many instances petrifactions which make it possible to study their microscopic structure, and these have furnished much valuable information as to the nature of some of the oldest known vascular plants. All the existing classes of pteridophytes can be traced back to the early Devonian formations and indicate that they have probably originated from independent but similar bryophytic ancestors.

As is so frequently the case, the most specialized of these ancient types have disappeared before their still more perfect descendants, while the lower and more generalized have persisted, or have left descendants which have been able to occupy positions to which more specialized forms are not so well adapted. Thus the giant pteridophytes of the Coal Measures have given way to the more modern trees, and to-day the tree-ferns alone remain to remind us of their past glories. The more humble ferns and club-mosses still play an important rôle in the vegetation where conditions are favorable, as in New Zealand and the mountain forests of the tropics; and a few, like the field horsetail (*Equisetum*) and the common bracken fern, manage to hold their own against the

predominant flowering plants, even in very unfavorable conditions.

Of the existing pteridophytes the ferns form a very large majority, but most of the types found in the older formations are now extinct and have been replaced by those now existing, which are of relatively recent origin and which have succeeded, like the still more recent flowering plants, in adapting themselves to existing conditions. Some of the modern tree-ferns rival in size their fossil prototypes. The other living pteridophytes, the horse-tails, club-mosses and Psilotales, are few in number, compared with the ferns, and are but poor relations of the giant Lepidodendrons and Calamites of the Coal Measures.

As the primitive land plants adapted themselves more and more perfectly to the increasingly diverse conditions associated with their new environment, the evidences of their aquatic ancestry became less apparent, and finally in the highest of all plant types, the seed plants, disappeared.

The mosses and ferns illustrate the transitional stages through which the seed plants have passed in their evolution from their primitive aquatic ancestors, the green algae. In the bryophytes the history of the gametophyte shows the limitations of this aquatic organism in adjusting itself to the radically different water conditions to which land plants are subjected. Even the most perfect gametophytes, such as those of the higher mosses, owing to their failure to develop adequate roots and efficient skeletal tissues, are unable to attain any but the most modest dimensions. Moreover, these plants are essentially amphibious and free water is necessary for fertilization.

In the ferns the development of the race centers in the sporophyte—the neutral generation. This, being the product of the fertilized egg-cell, is equivalent to the zygote or resting-spore of the ancestral green algae from which it is assumed that the mosses and ferns are descended. As the zygote of the algae is usually fitted to survive periods of drought, we may say that the sporophyte from its earliest beginning has been an organism fitted for life on land. It evidently has a potentiality for development on land that is not shared by the essentially aquatic gametophyte. It might be said that nature, having in the mosses exhausted her resources in the endeavor to transform the aquatic gametophyte into a successful land plant, turned to the spore-bearing generation as a more promising subject for experimentation. In the ferns, therefore, we meet for the first time a sporophyte which has true roots with sufficient capacity for water absorption to provide for the further development of the sporophyte, which thus becomes a perfectly developed land plant, with stem, leaves, roots and elaborately developed tissues.

With the increasing importance of the sporophyte there is a gradual reduction in the gametophyte, which becomes more and more insignificant, finally resulting in its reduction to minute, almost microscopic size in what are known as the "heterosporous" pteridophytes. These heterosporous forms occur in several unrelated groups, and it is evident that heterospory has been developed quite independently in these.

Heterospory is the first step toward the development of the seed habit. In the ordinary ferns the spores are all alike, and the gametophytes developed from them bear both male and female gametes. Occasionally from similar spores gametophytes of two sorts—male and female—are produced, and in such cases the male plants are smaller than the females. In the heterosporous forms, such as the water fern, *Marsilia,* sporangia of very different sizes are developed: large ones, in which only one very large spore—the megaspore—comes to maturity; and small sporangia, in which all the spores—microspores—develop. The gametophytes in both cases are reduced to a few cells and are retained within the spores, and the whole development of the gametophytes is completed within less than twenty-four hours. From the megaspore, the female gametophyte is formed; from the microspores, the male.

In the club-mosses of the genus *Selaginella,* the macrospores remain within the sporangium until the development of the gametophyte is far advanced and may even be retained permanently within it, and the growing gametophyte draws upon the tissues of the sporophyte for its nourishment, thus reversing the relation of sporophyte to gametophyte as compared with the lower archegoniates.

The seed is a further elaboration of the megasporangium. In the seed plants the megaspore is retained permanently within the sporangium, where it completes the development of the gametophyte and fertilization is effected. The embryo plant, enveloped in the double covering of the spore membrane and the sporangium wall, which becomes the shell of the seed, is very effectively protected from external vicissitudes, and during its development can draw upon the parent plant for its food supply. It moreover stores up in the ripe seed the reserve food which is necessary during germination. The advance of the resting stage of the plant, from the simple spore in the fern to the embryo within the seed, gives the seed plants a great advantage in the certainty and rapidity with which the new generation is established. The seed habit has resulted in a plant type peculiarly adapted to life on land, as is shown by the extraordinary development of seed plants at the present time.

All the primitive seed plants have their seeds ex-

posed on open leaves or scales, and are known as gymnosperms to distinguish them from the higher flowering plants, the angiosperms. Like the terms bryophyte and pteridophyte, these are convenient, but do not imply a necessary close relationship among all the members of the class.

The earliest seed plants, whose remains are found as far back as the Devonian era, were very different from any of the existing ones. Some of them were evidently related to the ferns and have been called pteridosperms or seed ferns. Others were related to the club-mosses, and still others are not clearly related to any existing types. The evidence that seeds were developed in a number of unrelated plants makes it extremely probable that the living seed plants also represent several independent lines of development.

Of the older types of seed plants still existing, the conifers—pines, firs, redwood, etc.—are the most numerous and familiar. The flowers of these are composed of closely set scales upon which are borne respectively the macrosporangia and microsporangia. The structure of these may be readily compared to that of some of the heterosporous pteridophytes. In the megasporangium a single large megaspore is formed within which a gametophyte with several archegonia is developed, much as in Sclaginella. The megaspore, however, is retained permanently within the sporangium, and this necessitates a quite different method of fertilization. The megasporangium in the seed plants is known as the ovule.

The microsporangia are much like those of the ferns, and the microspores are formed in tetrads, as in all typical archegoniates, and are called pollen-spores. A very rudimentary gametophyte with two sperms is formed within the spore. The ripe pollen spores fall upon the apex of the ovule (megasporangium) and send out a slender tube which penetrates the tissue overlying the archegonia and discharges the sperms into the archegonia. Unlike those of the ferns, the sperms have no cilia. The pollen tube does away with the necessity of water for effective fertilization, and the last trace of the aquatic origin of these plants disappears.

In a number of the most primitive seed-plants, especially the fern-like cycads, motile sperms have been discovered. In these the pollen tube becomes greatly distended by an accumulation of water, and finally bursts and discharges the water together with the large ciliated sperms into a chamber which lies above the archegonia. So we see that, even in the seed plants, the same aquatic type of fertilization may occur that obtains throughout the whole archegoniate series from which these plants are descended.

That the seed habit developed a number of times in quite unrelated groups of pteridophytes is amply shown by the fossil remains of seed-bearing plants in the Paleozoic, as far back as the Devonian. Some one, or perhaps more than one, of the seed ferns were probably the progenitors of the living cycads and the abundant cycad-like forms of the Mesozoic formations. The cycads at present are few in number or species, but widely dispersed, and seldom sufficiently abundant to make them important constituents of the vegetation.

The conifers are preeminently the predominant gymnosperms of the present. Although the number of species hardly exceeds four hundred, they nevertheless, owing to their gregarious habit, are among the most important forest trees in many parts of the world—especially here on the Pacific Coast. Incidentally, they include the largest known trees.

It is pretty clear that the existing seed plants do not form a homogeneous assemblage. The gymnosperms show evident relationships with the pteridophytes, but the different orders, *e.g.*, conifers, cycads, may very well have been derived from quite independent pteridophytic stocks. The predominant modern flowering plants or angiosperms differ so markedly from the gymnosperms that it is a question whether there is any real relationship between them, and their origin is very uncertain.

The production of the seed marks the final step in the complete adjustment of the plant organism to strictly terrestrial conditions, and while seeds arose independently in several widely separated classes, most of the primitive seed plants have disappeared completely, or have left only a few descendants which maintain a more or less precarious existence at the present time.

One type of seed plants, however, has proved itself eminently adapted to modern conditions and comprises an overwhelming majority of living plants. These are the familiar flowering plants, or angiosperms, to use the botanical term. In the angiosperms the plant organism reaches its most perfect expression, and they now dominate the land floras of the whole world.

Plastic to a degree unequaled by any other plants, they have adapted themselves to the most diverse conditions. From the burning deserts of the tropics to the utmost limits of vegetation in the polar regions and on mountain summits angiosperms have made themselves at home. A few have even invaded the sea, and many live in swamps or completely submersed in lakes or rivers. Others, like the mistletoe or dodder, have adopted a parasitic life, and still others live at the expense of dead organic matter—or as we say are saprophytes, like the snow-plant of our high mountains. The parasitic and saprophytic

angiosperms recall the fungi, and as they have more or less completely lost their chlorophyll, must depend on other organisms for their organic food. While the ferns and gymnosperms have left abundant and well-preserved fossil remains whose nature is unmistakable, of the angiosperms, except in the later geological formations, only scanty traces have been found, and these are often of very doubtful nature.

It is not until the later Mesozoic formations are reached that certain evidences of angiosperms are encountered. From the Cretaceous upward, they rapidly increase in number and variety, and many existing types can be plainly recognized among the Cretaceous fossils.

The apparent sudden appearance of angiosperms in the lower Cretaceous rocks and the close resemblance of these early fossils to living types make it certain that there must have been a long line of more primitive forms preceding them; but of these "protangiosperms" we have no definite evidence, and at present there is much controversy as to what was the origin of the angiosperms.

The flowers of the angiosperms are much more highly developed than those of the gymnosperms, and it is difficult to compare them. The young seeds, or ovules, instead of being exposed on an open scale, as in the pine, are contained in a closed receptacle (ovary) usually composed of special leaves, or carpels, grown together. The development of the seed, however, is much the same as in the gymnosperms—except that the gametophyte is very much more reduced. The microsporangia, or pollen sacs, are borne on specially modified leaves, the stamens—and the stamens and carpels are the essential organs of the angiosperm flower.

The flower may consist of only stamens or carpels, and the two sorts of flowers may be on the same plant, as in the oak or corn, or they may be on different individuals, as in the poplars, willows and the date palm. As some of the oldest fossil angiosperms, like the poplars and sycamore, have such "diclinous" flowers, it is probable that this condition is more primitive than the much more common "perfect" flowers having both stamens and carpels. Many botanists, however, believe that the diclinous condition is the result of reduction from flowers having both stamens and carpels, but there are serious objections to this view.

Most of our common flowers are "perfect" or "hermaphrodite"—or to use a more accurate term, amphisporangiate. Moreover they usually possess a conspicuous floral envelop, which may be composed of nearly uniformly colored leaves, as in a lily, or there may be a double envelop—the green calyx and the highly colored corolla. As we have already noted, the ovules are borne in a closed ovary, which may be the base of a single carpel or may be formed by the junction of several carpels into a compound pistil.

The position of the ovules in the closed ovary requires special adaptations for insuring fertilization. In the gymnosperms the pollen spores fall directly upon the apex of the exposed ovule. In the angiosperms there is a special organ—the stigma at the tip of the pistil—which receives the pollen and facilitates its germination. The pollen tube grows downward through the tissues of the pistil until it reaches the ovule in the ovary, and fertilizes the egg-cell in much the same way as in the gymnosperms, and the subsequent development of the seed is very similar.

The effect of fertilization extends to the carpels, which are stimulated in growth and at maturity enclose the ripe seed in a fruit. This not only serves to protect the ripening seed, but is concerned also with its distribution. The development of the fruit has undoubtedly been an important factor in the success of the angiosperms in the struggle for existence.

The simple diclinous flowers of a poplar or oak might in a way be compared with the flowers of a pine, and as in the pine, there is a very large amount of light pollen formed, which must depend on the wind to carry it to the pistil. In the somewhat more specialized floral types, the stamens and carpels are close together, and there is a definite floral envelop. The number of parts is often indefinite, but with the increasing specialization the flower shows a constant number in its members, and the corolla becomes bright colored. Further specialization results in tubular flowers, sometimes of peculiar form. A study of these changes in form and color and the development in many flowers of characteristic scents shows very clearly that these are associated with the pollination of the flowers, mainly through insect agency.

Just when the association with insects as agents in pollination—entomophily as it is called—became established and thus started the extraordinary evolution of both insects and angiosperms is impossible to determine.

That the earliest angiosperms were entomophilous is exceedingly doubtful. The earliest known are allied to forms which at the present time have inconspicuous wind-pollinated flowers. Moreover, what is known of the insects of this period indicates that none of the specialized insects, like bees and butterflies, had yet come into existence; but later on, the rapid increase in the number and variety of the angiosperms indi-

cates that entomophily had begun to exercise a marked influence on their evolution.

The development of a showy corolla, which has been thought might have arisen from a transformation of stamens such as we may still see in some double flowers, is associated with the entomophilous habit, and it is by no means unlikely that the development of a true corolla was preceded by a condition in which the stamens, otherwise unchanged, became colored, and thus attractive to insects visiting the flower for pollen or honey. Such a condition may still be found, for example, in *Eucalyptus* and *Acacia,* where a corolla is either quite wanting or is relatively inconspicuous.

There is no question that the extraordinary numbers and diversity of the angiosperms are in very large measure the result of their adaptation to cross-pollination through insect agency. The seeds of cross-fertilized flowers have been shown to be more numerous and the seedlings more vigorous than those from self-pollinated flowers. It is also a legitimate assumption that increased variability due to crossing is advantageous in tending to develop new characters which are subject to natural selection. While insects are the principal agents in cross fertilization, certain birds may also act in this capacity. In America the humming-birds are familiar examples. They seem to show a special preference for red flowers, like the scarlet sage, fuchsias and some of the pentstemons, *Zauschneria,* etc. In other parts of the world, *e.g.,* South Africa, the sun-birds play a similar rôle, and these, too, seem to have a penchant for bright red. The aloes and red-hot poker in our gardens are examples of old world ornithophilous flowers.

While we may hesitate to accept all the conclusions of the enthusiastic students who first realized the immense importance of entomophily, we have no reason to doubt that the course of evolution of the two largest groups of plants and animals, angiosperms and insects, has been powerfully influenced by the mutual adaptations that have arisen in the association of these two groups of organisms.

The great variety of fruits developed in the angiosperms and the correspondingly varied devices for the distribution of the seeds have also been important factors in their success.

The early history of the angiosperms is very obscure, and we have no satisfactory evidence of their existence prior to the Cretaceous. The general uniformity of their essential structures makes it pretty certain that they have all originated from some common stock—or at least from some assemblage of related forms from which a number of lines of true angiosperms diverged. The prevalent division into two coordinate subclasses, monocotyledons and dicotyledons, is probably a somewhat artificial one. It is more likely that from an undifferentiated widespread primitive stock, for which the name protangiosperms has been proposed, a number of lines of true angiosperms arose, some monocotyledons, others dicotyledons.

Once established, the angiospermous type showed itself to be remarkably adaptable, and it soon established itself as the dominant element in the land vegetation. Whence arose their extraordinary plasticity can only be conjectured. The type of fruit, with the complete protection of the seed until its maturity, may have been one of the important factors in establishing their superiority over the gymnosperms; but this will not explain the extremely plastic plant body which contrasts so strongly with the limitations of the gymnosperms.

It may be that cross-fertilization among angiosperms arose early in their history and that thus a greater degree of variability was induced, resulting in the appearance of many modifications which could be seized upon by natural selection and thus tend to develop new types. Whatever may have been the reasons, it is their extraordinary adaptability that is at the bottom of the remarkable success of the angiosperms. One important phase of this is the utilization of animals for the distribution of pollen and seeds. Nearly all plants whose organs have been modified with reference to animal structures are angiosperms, and the great variety of flowers and fruits is doubtless connected with such adaptations. However uncertain we may be as to their origin, the remarkable fitness of these plants to modern conditions is obvious, and they have largely monopolized the land areas of the whole world. Only under exceptionally favored conditions are the lower plant types able to hold their own in competition with the all-conquering angiosperms.

OBITUARY

RECENT DEATHS

DR. IRA NELSON HOLLIS, professor of engineering at Harvard University from 1913 to 1925 and president of the Worcester Polytechnic Institute from 1893 to 1913, died on August 15, at the age of seventy-four years.

DR. LOUIS MURBACH, for many years head of the department of biology in the Central High School,

Detroit, died on July 24, aged sixty-six years. Dr. Murbach had been instructor in zoology at the University of Michigan and at Woods Hole and is known for his work on invertebrate zoology.

WALTER DEANE, botanist and ornithologist, known for his work on the flora of northeastern North America, died on August 3. He was in his eighty-third year.

DR. ASA BARNES DAVIS, chief surgeon at Lying-in-Hospital, New York City, known for his work in obstetrics, gynecology and abdominal surgery, died on August 13. He was sixty-eight years old. Dr. Davis was one of the founders of the American College of Surgeons.

W. J. GREENSTREET, formerly headmaster of Marling School and for thirty-one years editor of the *Mathematical Gazette* of the British Mathematical Association, died on June 28 at the age of sixty-nine years.

DR. CORNELIO DOELTER, of Vienna, an expert in precious stones, died on August 12 at the age of eighty years. He was a professor of the University of Vienna, where he lectured on mineralogy and the chemistry of minerals.

MEMORIALS

FRIENDS and associates of the late William Stanley, inventor of the electrical transformer, gathered at Fairview Hospital, Great Barrington, on August 6 to dedicate to his memory an elaborately equipped X-ray room. Forty-four persons and corporations, including the General Electric and Westinghouse Companies, gave $35,000 to equip the room and endow it. Mr. Cummings C. Chesney, of Pittsfield, a vice-president of the General Electric Company, made the presentation address. Mr. Chesney and Frederick Darlington went to Great Barrington in 1888 as the two original assistants to Mr. Stanley in his early laboratory work there. T. Ellis Ramsdell, president of the Fairview Hospital Corporation, accepted the gift, which had been suggested by the late Ralph W. Pope. Mrs. William Stanley and four of six sons were present at the ceremony.

THE *British Medical Journal* writes: "The Osler Club celebrated, on July 12 at its headquarters in London, the eighty-first anniversary of the birthday of Sir William Osler. Professor Harvey Cushing, having been welcomed as a friend of the club and as orator, gave an informal address, full of the charm and the whimsicality of his subject. He told of the early Weston days, of Father Johnson and of James Bovell, and of how under their influence Osler turned from the church to medicine. Professor Cushing, in his address, revealed some of the secrets of the writing of 'The Life,' and much else besides, to the delight of his audience. Dr. Arnold Klebs took up the tale, to be followed by Sir Arthur Keith. Between the three, with occasional help from Sir D'Arcy Power, Dr. Henry S. Wellcome and Mr. Philip Franklin, a lively discussion continued, until Mr. W. R. Bett, foreign secretary of the club, remembered that it was long past Osler's bedtime, and with a graceful tribute to the orator and to the influence of 'The Life' upon the growing generations of medical men, brought the meeting to a happy conclusion. Before the oration the club entertained Professor Harvey Cushing to dinner at the Langham Hotel."

THE *Journal* of the American Medical Association reports that Professor Paul Krause, Münster, president of the Rheinisch-Westfälische-Röntgen Society, has announced a plan to erect a monument to Röntgen in the birthplace of Lennep. The plan is to raise one fourth of the cost of the monument or $2,500 from American röntgenologists. So far $900 has been raised and it is hoped that the remaining $1,600 will be contributed by 1,200 röntgenologists who have not yet responded. Contributions are to be sent to Dr. Otto Glasser, 2050 East Ninety-Third Street, Cleveland, Ohio.

THE offer of Professor S. Smiles and Professor A. J. Allmand to found a medal at the University of London to commemorate the services rendered to King's College and to chemical education by Professor John Millar Thomson, LL.D., F.R.S., has been accepted with thanks by the university. Professor Thomson first became a member of the staff of the department of chemistry at King's College in 1871, and retired in 1914, after having served for twenty-seven years as Daniell professor and head of the department of chemistry. The medal will be known as the John Millar Thomson Medal for Chemistry and will be awarded annually to the student of King's College who most distinguishes himself in the final year of the special honors course in the department of chemistry.

SCIENTIFIC EVENTS

THE FARADAY CENTENARY

THE following account is given by the London *Times* of arrangements being made by the Royal Institution for the celebration in September, 1931, of the discovery by Michael Faraday of electromagnetic induction, in which lies the origin of the dynamo and which is the starting point of the utilization of electric power for the purposes of man.

The day of the discovery was August 29, 1831. On that day Faraday, as his diary shows, working in his laboratory at the Royal Institution, wound two coils of wire on to opposite sides of a soft iron ring, connected one coil to a battery and the other to a galvanometer, and at the "make" and "break" of the battery circuit observed the deflections of the galvanometer connected in the other circuit. From this simple experiment and the variations made in it by Faraday in subsequent trials has grown in the past one hundred years the science of electrical engineering. The Royal Institution, in a preliminary announcement of the proposed celebrations, says: "No other experiment in physical science has been more fruitful in benefit for mankind. August 29, 1931, is, then, the centenary of one of the great events in the history of the world."

The Royal Institution and the Institution of Electrical Engineers have joined forces in making plans for the celebrations, and a number of other societies and organizations are cooperating. The Royal Society will entertain the delegates; the British Association has arranged the dates for its centenary meeting in London, also in 1931, to coincide with the Faraday celebrations; the Federal Council for Chemistry will participate in the arrangement of a Faraday Exhibition, for Faraday's chemical researches—his isolation of benzene and his establishment of the laws of electro-chemistry—are hardly less remarkable than his purely electrical discoveries, and government, university and scientific interests have joined in offering their assistance to make the celebrations worthy of the occasion.

The provisional program includes a Faraday Commemorative Meeting at the Queen's Hall on Monday, September 21, 1931, at which addresses will be given on Faraday's work. On Tuesday the summer meeting of the Institution of Electrical Engineers, with joint conference of allied associations, will be held; on Wednesday morning there will be the opening of the Faraday Exhibition to the public at the Albert Hall, and in the evening the opening meeting of the British Association will be held at the Central Hall, Westminster.

Faraday kept a careful diary, in his own hand, of all his experimental work, which was bequeathed to the Royal Institution and for over sixty years has been its most treasured possession. The Royal Institution has resolved to publish the diary in full. It is intended to have two or more of the six or eight volumes in which the work will ultimately be completed ready by September, 1931. It will be issued by Messrs. G. Bell and Sons, Limited, York House, Portugal-street, W.C.2.

EXPLORATIONS IN AFRICA

A WIRELESS to the New York *Times* dated from London states that data and relics of the African explorations of David Livingstone and Sir Henry Stanley have been found by Colonel Charles Wellington Furlong, an American explorer, artist, author and lecturer, who arrived in London on August 13 *en route* to the United States following a seven months' expedition into the heart of Africa.

While the chief purposes of the expedition, which covered 7,000 miles in Kenya, Tanganyika, Uganda, the Belgian Congo and the West Nile Provinces, were an ethnological study of African tribes and big game hunting as well as a study of political, economic and social conditions, Colonel Furlong was desirous of finding whatever traces remained in Africa of Livingstone and Stanley.

In a Belgian Congo village he found Chief Godoy, a son of Chief Matibu, the most important native associate of Sir Henry Stanley, from whom he learned many facts of considerable interest about Stanley and the others of his expedition and about Chief Matibu himself. Chief Godoy had carefully preserved many of his father's relics, including his favorite spearhead, carried when he was with Stanley, a remarkable letter of appreciation written to Chief Matibu by Lady Stanley in 1911, an elaborate gold headdress which she sent therewith and a bracelet given to Chief Matibu by Sir Henry. All these things Colonel Furlong bought from Chief Godoy.

"Precious as they were to him," said Colonel Furlong, "I was able to convince him that in some museum they would better preserve for posterity the record of Chief Matibu's association with Stanley, whereas in the jungles they could easily be lost. He sold them on the condition that I return to him framed photographs of Lady Stanley's letter and other relics to be hung on the walls of his hut where all the natives could admire them."

In South Mombasa Colonel Furlong located a native about ninety years of age who is the only surviving member of Livingstone's expedition. He was one of five who went into the interior with Livingstone when he died and bore on his shoulders the explorer's mummified body from the jungles of Africa. Colonel Furlong spent six hours getting this man's story, the details of which, as well as the Stanley data, he intends to publish on his return to the United States.

THE FOURTH WORLD POULTRY CONGRESS

THE Fourth World Poultry Congress, which was opened at the Crystal Palace by the Duke of York on July 22, closed on July 30. The London *Times* reports that during the congress 2,400 delegates and members registered from 61 countries, and about 80,000 people passed the turnstiles.

At the final assembly of delegates and members, presided over by Mr. F. C. Elford (Canada), president of the World Poultry Science Association, an address was sent to the King expressing appreciation of the manner in which the government and departments of state had organized the congress and exhibition, and of the hospitality accorded to them.

A resolution was also adopted thanking the Governments of Great Britain and Northern Ireland and the Ministry of Agriculture and Fisheries for the welcome accorded to the delegates and their admiration of the organization of the congress and exhibition. Another resolution thanked the World's Poultry Science Association, which initiated the congress; the congress officials, with special acknowledgment of the services of Mr. Percy A. Francis, director, and Dr. Wilkins, secretary; the committees and the hosts on various excursions, and to Mr. H. J. Buckland, general manager of the Crystal Palace.

Several resolutions were submitted from the various conference sessions. The education and general section passed a resolution, by seventeen votes to seven, "that the various government departments and egg-laying competition committees conducting egg-laying competitions be asked to consider the advisability of introducing the 2 oz. standard from the beginning of the competition." This was amended by the addition of the metric equivalent, 56.7 grams, and adopted.

Another resolution, adopted unanimously by the education and general section, was "that during the next three years the council of the World's Poultry Science Association draw up, with the assistance of sub-committees, universal standards for all the different breeds of poultry, such standards to be submitted to the next World's Poultry Congress." The feeling of the assembly was that although international standards represented an ideal to which all would subscribe, it was not sufficiently practical to justify taking up the time of the next congress, and the resolution was not adopted.

The diseases section unanimously recommended "That the attention of the various governments be drawn to the danger of the importation of 'Newcastle' (or 'Ranikhet') disease, with a view to suitable measures being taken for its exclusion and control in each country." On the suggestion of Dr. te Hennepe (Holland) the name "pseudo fowl pest" was preferred to "Newcastle" disease, and with this amendment the resolution was adopted.

The economics section resolved that it was a matter of urgent importance that each government should include poultry statistics in every agricultural census. This was adopted without discussion.

The economics section also adopted a resolution, on the motion of the Dutch delegates, expressing the view that all eggs cold stored in any country should be stamped with an internationally agreed mark. Amendments were submitted to include gas-stored as well as cold-stored eggs. In this form the resolution was carried. The assembly also adopted a resolution asking the International Institute of Agriculture at Rome to convene a conference to discuss an international scheme for identifying stored eggs.

HONORARY DEGREES CONFERRED BY LEHIGH UNIVERSITY

Lehigh University conferred at the commencement the honorary degree of doctor of engineering on Mr. Thaddeus Merriman, '97, son of the late Mansfield Merriman, who was professor of civil engineering at Lehigh for almost thirty years, and the degree of doctor of science on Commander Nicholas H. Heck, '03, chief of the division of terrestrial magnetism and seismology of the United States Coast and Geodetic Survey.

In presenting Mr. Merriman to President Richards for the degree, Professor Ralph J. Fogg, head of the department of civil engineering, gave the following outline of his career and accomplishments:

Thaddeus Merriman, whose noteworthy accomplishments and engineering skill have gained for him the distinction of being one of America's chief authorities on municipal water supply, is presented for the honorary degree of doctor of engineering.

Graduating from Lehigh in 1897 with the degree of civil engineer, Mr. Merriman received his early experience on geological reconnaissance work in Pennsylvania and surveys for the United States, Nicaragua and Isthmian Canal Commissions.

Since 1902 he has been in continuous service in the water works field, starting with the Jersey City Water Supply Company as assistant engineer on the Boonton Dam, and later as division engineer with the East Jersey, Passaic and Acquackanonk Water Companies. He has served on the engineering staff of the Board of Water Supply of the City of New York for twenty-five years, receiving successive promotions to his present responsibility as chief engineer, which position he has filled since 1922. Under his direction was prepared the plan for a new water supply from the upper tributaries of the Delaware River; the estimated cost of this project, including the delivery of water into New York City, being over three hundred million dollars.

In 1918 Mr. Merriman was called to Greece for the purpose of investigating the proposed water supply for the city of Athens. Last fall he was signally honored by being made chairman of the Board of Engineering Review of the Metropolitan Water District of Southern California.

It is interesting to recall that on Founder's Day, seventeen years ago, the honorary degree of Doctor of Laws was conferred on Mr. Merriman's father, Mansfield Merriman, Lehigh's great writer and teacher of engineering.

President Richards's citation follows:

Thaddeus Merriman, loyal son of Lehigh, distinguished in service with the U. S. Nicaragua Canal Commission, with the U. S. Isthmian Canal Commission and with the Board of Water Supply of New York City, now chief engineer of the latter, contributor to the science and practice of hydraulics and water supply engineering as

notably exemplified in the design and construction of the Catskill Water Supply System.

Commander Heck was presented to President Richards for the degree of doctor of science by Professor C. C. Bidwell, head of the department of physics, with the following brief sketch of his achievements:

Commander Heck is a graduate of Lehigh University of the Class of 1903. He has achieved high distinction in his chosen field and is a recognized authority on seismology and terrestrial magnetism. He is the author of many scientific papers and publications of the Coast and Geodetic Survey. Among these are the following titles: "Radio Acoustic Method of Position Finding in Hydrographic Surveys," "Earthquake History of the United States," "Report on Network of Earthquake Observations of Countries bordering the Pacific," "Values of the Velocity of Sound for Echo Soundings in the Pacific Ocean," "Oceanography and Seismology in the Pacific Region," etc. It is a privilege to present to you Commander Heck for this degree.

In conferring the degree President Richards said:

Nicholas Hunter Heck, loyal son of Lehigh, recognized for distinguished service with the U. S. Coast and Geodetic Survey as commander of the schooner *Matchless* and of the steamer *Discovery*, and as chief of the Division of Terrestrial Magnetism and Seismology, contributor to the science of deep sea sounding, the compensation of the magnetic compass and the study of earthquakes.

SCIENTIFIC NOTES AND NEWS

The Mueller Memorial Medal of the Australian Association for the Advancement of Science was awarded at the recent meeting at Brisbane, which was held from May 28 to June 4, to Sir Douglas Mawson for his contributions to Australian geology, associated with which are his achievements in geography and exploration. The first Liversidge Research Lecture under the bequest from the late Professor A. Liversidge was delivered by Professor N. T. M. Wilsmore, of the University of Western Australia, the title of the lecture being "Chemical Research and the State." At this meeting it was decided to change the name of the association to "The Australian and New Zealand Association for the Advancement of Science."

The Moxon gold medal of the Royal College of Physicians, London, awarded every third year to the person who is deemed most to have distinguished himself by observation and research in clinical medicine, has been awarded to Dr. Frederick Parkes Weber. The Weber-Parkes prize and medal, awarded every third year for work on the etiology, prevention, pathology or treatment of tuberculosis, has been awarded to Professor S. Lyle Cummins.

The honorary gold medal of the Royal College of Surgeons, London, has been awarded to Mr. R. Lawford Knaggs, in appreciation of his services to the museum, more especially in preparing a catalogue of and revising the Strangeways collection of specimens illustrating arthritis.

The special gold medal awarded by the Congress to Colonel Charles A. Lindbergh, to commemorate his achievements in the advancement of the science of aviation, was presented to him by President Hoover on August 15.

In appreciation of the service given to the University of California Medical School by Dr. William Palmer Lucas, for several years head of the department of pediatrics, who retired at the close of the academic year, members of his staff recently held a banquet and presented him with a gold watch purchased with contributions from students of every one of the seventeen years.

"As a token of appreciation of his outstanding civic services," the citizens of Tallulah, Louisiana, have presented to B. R. Coad, in charge of the cotton-insects division of the Bureau of Entomology, having its headquarters in their town, a motion-picture camera and projector. This presentation was made at a meeting of the Business Men's Luncheon Club of Tallulah, of which Mr. Coad recently was elected an honorary member.

The Poultry Science Research Prize of $100, which is awarded annually to the member of Poultry Science Association who publishes the most outstanding piece of research contributing to the furtherment of the poultry industry, has been awarded to Dr. F. A. Hays, of Massachusetts, for his work "Inbreeding in Relation to Egg Production." Honorable mention was given the paper of Dr. D. C. Warren, of Kansas, on "The Inheritance of Rhode Island Red Chick Down-Color Variations and their Relation to Color Variations in Adult Plumage," published in the November 15, 1929, issue of the *Journal of Agricultural Research*, and to the paper by Hendricks, Lee and Titus, "Early Growth of White Leghorns," published in *Poultry Science* for September 1, 1929. The check for $100 was presented to Dr. Hays at the annual banquet of the Poultry Science Association by J. Holmes Martin, secretary-treasurer of the association.

The Harveian oration of the Royal College of Physicians in 1931 will be delivered by Dr. Robert

Hutchison. The Bradshaw lecture will be given by Dr. J. S. Fairbairn.

THE Council of the City and Guilds of London Institute has conferred the distinction of fellow of the institute upon the following: F. M. Denton, A. H. Dykes, W. M. Heller, E. M. Rich and F. F. Renwick. The fellowship is conferred by the council upon those who, having obtained the associateship of the institute and spent at least five years in actual practice, produce evidence of having done some original and valuable research work or of having otherwise contributed to the advancement of the industry in which they are engaged.

MR. R. W. TRULLINGER, assistant in experiment station administration and senior agricultural engineer of the Office of Experiment Stations, was elected president of the American Society of Agricultural Engineers at the recent annual convention at Moline, Illinois.

PROFESSOR LEWIS ROBERTSON SUTHERLAND has resigned from the chair of pathology at St. Andrews University.

THE following officers of the Royal College of Surgeons, London, have been elected for the ensuing year: *President,* Lord Moynihan; *Vice-presidents,* Mr. C. H. Fagge and Mr. R. P. Rowlands; *Physiological curator,* Mr. R. H. Burne; *Pathological curator,* Mr. C. F. Beadles; *Honorary curator of Odontological Collection,* Sir Frank Colyer; *Honorary curator of the Historical Collection,* Mr. C. J. S. Thompson.

PROFESSOR OWEN THOMAS JONES, of Trinity College, professor of geology and mineralogy at the Victoria University of Manchester, has been elected to succeed Professor J. E. Marr, of St. John's College, who will retire from the Woodwardian professorship of geology at the University of Cambridge on September 1.

AT the University of Cambridge Dr. J. M. W. Morison has been appointed to the university chair of radiology, tenable at the Cancer Hospital; Dr. H. D. K. Drew to the university readership in organic chemistry, tenable at East London College; Sir Arthur Evans, fellow of Brasenose College, Oxford, to the Frazer lectureship in social anthropology for the academical year 1930–31, and the appointments committee of the Faculty of Agriculture and Forestry has appointed H. E. Woodman, of Downing College, university lecturer in agricultural chemistry for three years from October 1, 1930, and W. K. Hubble, of Downing College, university demonstrator in agriculture for a like period. With the concurrence of the Ministry of Agriculture and Fisheries, Dr. Marshall was appointed director of the Animal Nutrition Institute from August 1.

DR. H. W. GILLETT, director of Battelle Memorial Institute, announces the following additions to the staff: Dr. O. E. Harder, assistant director; Dr. C. H. Lorig, metallurgist; Samuel Epstein, metallurgist, and L. H. Grenell, metallurgist. Dr. Harder has been professor of metallography at the University of Minnesota during the past eleven years and was also engaged in consulting work. He had previously been with the Portland Cement Association, the N. K. Fairbanks Company and the Mellon Institute. Dr. Lorig came directly from Drexel Institute, where he was professor of mechanical engineering in charge of their metallurgical courses, and will study foundry and general metallurgical problems at Battelle. He has had experience with the Wisconsin Steel Company, the Wisconsin Appleton Company, the French Battery Company and the Laddish Drop Forge Company. Mr. Epstein has been research metallurgist for the Illinois Steel Company and metallographer at the U. S. Bureau of Standards and will have charge of a research on the embrittlement of steel—one of the sponsored projects of Battelle. Mr. Grenell has been with the Ingersoll-Rand Company, the Bureau of Mines, the Bureau of Standards and the Frigidaire Corporation. He will study the production and utilization of metal foils—another sponsored project.

DR. FRED N. BRIGGS, of the office of cereal crops and diseases of the U. S. Department of Agriculture at Berkeley, California, has been appointed assistant professor of agronomy at the University of California and assistant agronomist of the Agricultural Experiment Station.

THE Frederick G. Donnan fellowship in chemistry, tenable for three years at the Johns Hopkins University, has been awarded to Mr. Alkin Lewis, of King's College, London.

DR. J. L. COLLINS, assistant professor of genetics at the University of California, has been appointed geneticist for the experiment station of the Association of Hawaiian Pineapple Canners, University of Hawaii, and is now in Honolulu.

THE *Experiment Station Record* reports that Dr. E. C. Stakman, professor of plant pathology and plant pathologist of the University of Minnesota, has been granted leave of absence to aid in organizing biological research in connection with a 50,000-acre rubber plantation in Liberia, which is being established by an American tire company. Arthur F. Verrall, instructor in plant pathology and assistant plant pathologist and botanist, accompanied him on this trip and

is expected to remain for a longer period to oversee the experimental work of the company until it is well under way.

DR. SAMUEL J. HOLMES, professor of zoology at the University of California, who has been traveling in Europe during the past year, has returned to Berkeley.

DR. ROBERT K. NABOURS, who is spending the year as associate in the department of genetics of the Carnegie Institution at Cold Spring Harbor, will return to the Kansas Agricultural College on September 1.

DR. ALEXANDER SILVERMAN, head of the department of chemistry of the University of Pittsburgh, sailed on August 21 for Europe. He will visit educational and research institutions in France, Holland and Belgium, and will attend the Tenth International Congress of Industrial Chemistry at Liége, Belgium, during the week of September 7, as a delegate from the American Ceramic Society, and the tenth International Union of Pure and Applied Chemistry, also at Liége, during the week of September 14, as one of fifteen delegates from the National Research Council and the National Academy of Sciences.

DISCUSSION

RELATIVE LENGTH OF PLEISTOCENE GLACIAL AND INTERGLACIAL STAGES

IN a report by R. T. Chamberlin[1] dealing with fluctuations of sea-level as controlled by glaciation, an estimate is presented of the percentage of the Pleistocene glacial epoch involved in glacial as compared with interglacial stages, and also an estimate of the percentage of time in a glacial stage in which the ice-sheets were at about their greatest extent. The estimates were given him by ten American glacialists who had had considerable experience in the study of glacial deposits in North America. In this composite estimate the glacial stages were given only one fourth the length of the interglacial stages, or 20 per cent. of the time involved in the Pleistocene glacial epoch. It was estimated by seven of the ten glacialists (three failing to give estimates) that the ice-sheet was at about its greatest extent for only one fifth of a glacial stage, or 4 per cent. of the glacial epoch, being in process of advance and retreat for four fifths of the glacial stage or 16 per cent. of the glacial epoch.

It now appears from a study of the distribution of moraines developed in the Wisconsin stage of glaciation that there was very little difference in the area covered by the ice-sheet throughout the greater part of that glacial stage, or from the time of the outermost Early Wisconsin moraine, the Shelbyville, to the time of the outermost Late Wisconsin moraine, the Port Huron. By extensive westward growth in Middle and Late Wisconsin time beyond the limits reached in Early Wisconsin time, the shrinkage shown by the exposed part of the Early Wisconsin deposits in the south part of the area was counterbalanced by the greater westward extent in higher latitudes. This shifting seems to have been due to a greater nourishment on the western side of the ice-sheet rather than to a change to higher temperature. The southern part became undernourished and showed a corresponding shrinkage. In view of these conditions it is probable that not less than 60 per cent. of the Wisconsin stage should be allotted to the culmination, and 20 per cent. each to the advance and the retreat of the ice-sheet.

From a study of the recession of Niagara Falls by Spencer, Taylor and others[2] it appears that the Port Huron morainic system, which marks the limits of the Late Wisconsin drift, was formed some 25,000 to 30,000 years ago. It also appears from a study of the Falls of St. Anthony on the Mississippi by Winchell, Grant and especially by Sardeson[3] that the outlet of the Glacial Lake Agassiz did not shift to Hudson Bay until some 8,000 to 10,000 years ago. This being the case the Wisconsin ice-sheet persisted in central Canada to within 10,000 years of the present time. It also appears that a period of about 15,000 years is involved in the retreat from the Port Huron moraine to the breaking up of the ice-sheet in central Canada. If then this retreat represents 20 per cent. of the time involved in the Wisconsin stage of glaciation, the length of this glacial stage is some 75,000 years and its beginning about 85,000 years ago. If then the culminating phase involved three fifths of the entire glacial stage, it endured some 45,000 years.

Estimates of the relative ages of the Kansan, Illinoian and Wisconsin drifts are based mainly on the erosion each has suffered. The Kansan drift appears to have been eroded to such a degree that an average of fifty feet of material would be required to restore the original surface as left by the withdrawal of

[1] Rollin T. Chamberlin, "Geological Interpretation of the Coral Reefs of Tutuila, American Samoa," pp. 145–178, Publication 340, Carnegie Institution of Washington, 1924.

[2] See Niagara Folio, U. S. Geological Survey.

[3] See St. Paul-Minneapolis Folio, U. S. Geological Survey.

the Kansan ice-sheet. The Illinoian drift is sufficiently eroded to require about fifteen feet for its restoration. The Early Wisconsin drift seems to need only five feet and the Middle and Late Wisconsin still less. The Iowan drift is too thin and patchy to furnish a basis for measurement of its erosion. The Nebraskan drift is so completely covered by the Kansan that its degree of erosion can not well be determined. That it is much older than the Kansan drift is known, however, from the development of gumbotil on its surface prior to the burial beneath the Kansan drift, and also by deep leaching and oxidation. On the basis of relative erosion the Illinoian drift appears to be about three times as old as the Early Wisconsin drift. Taking the estimates given above, the outer part of the Early Wisconsin drift is about 70,000 years old, in which case the age of the outer part of the Illinoian can be put at about 200,000 years. The close of the Illinoian glacial stage, however, may be between 150,000 and 175,000 years ago. The age of the Kansan drift appears to be more than a half million years and may reach three fourths of a million. The Nebraskan is probably a million years old.

There is no question of the occurrence of long interglacial intervals of relatively warm climate between the Nebraskan and Kansan glacial stages and between the Kansan and Illinoian stages. The latter appears to be more than four times the length of the Wisconsin glacial stage and thus to bear out the estimate made by glacialists and reported by Chamberlin. But there seems need for a recalculation of interglacial intervals between the Illinoian and Wisconsin glacial stages. The place and rank of the Iowan glaciation are also of importance in this connection.

An early interpretation that the Iowan is a distinct glacial stage falling between the Illinoian and Wisconsin glacial stages is still stoutly adhered to by several glacialists, but the present writer and also T. C. Chamberlin have expressed the view that the Iowan may stand as the western or Keewatin phase of the same glacial stage as the Illinoian and have a similar relation to it that the Late Wisconsin drift has to the Early Wisconsin.

If the Iowan is a distinct glacial stage, falling between the Sangamon and Peorian interglacial stages, it should fill a considerable part of the interval separating the Illinoian and Wisconsin stages and thus leave a very brief interglacial stage between it and the Illinoian stage, as well as between it and the Wisconsin stage. As a separate glacial stage the Iowan would probably embrace at least 30,000 years, the time estimated for the advance and disappearance of the Wisconsin ice-sheet. Taking the above estimate that the Illinoian glaciation ended 150,000 to 175,000 years ago and that the Wisconsin glaciation began about 85,000 years ago, there would be an interval of between 65,000 and 90,000 years between these two glacial stages. If the Iowan glaciation occupied 30,000 years in the midst of this interval, there would remain 35,000 to 60,000 years to be divided between the Sangamon and Peorian interglacial stages. In case of so brief interglacial intervals it may be more consistent to regard the Illinoian, Iowan and Wisconsin as a triple glaciation occupying the 200,000 years since the culmination of the Illinoian glaciation, and consider the Sangamon and Peorian times of slightly increased warmth between times of low temperature, causing a marked retreat of the ice border but not having the duration or degree of warmth of a true interglacial stage. This raises the question whether the ice had disappeared in the Sangamon or the Peorian interval to as great degree as at the present time in the northern part of the North American continent. The data at hand do not seem to be decisive on this matter.

It is of interest in this connection to note that Dr. Paul Woldstedt, a member of the Prussian Geological Survey, after spending a summer in the study of the North American drifts, in order to clear up correlations with the drifts of Europe, on which he had made extensive studies, has placed the Iowan drift in the midst of the European third interglacial stage in his recent book "Das Eiseitalter."[4]

The present writer, as already indicated, favors the reference of the Iowan drift to the same glacial stage as the Illinoian and places it near the close of the third glacial stage, about as the Late Wisconsin came in the last glacial stage. The combined Illinoian-Iowan, it is thought, may have covered a period similar to that of the Wisconsin, about 75,000 years, from say 210,000 down to 135,000 years ago, leaving an interval of 50,000 years between its close and the beginning of the Wisconsin stage. On this interpretation, as on that of a separate Iowan glaciation, it is an unsettled question whether the northern part of the North American continent was deglaciated to the present degree in this interval. The well-known Toronto interglacial beds suggest a warmer climate than the present, but it is not certain that they fall in this interglacial stage. They may prove to belong in the second, or Yarmouth, interglacial stage.

The Iowan drift displays a conspicuous pebbly concentrate on its surface, developed before the surface coating of loess was laid down. The development of this concentrate the present writer is disposed to refer to the Sangamon interval and consider a somewhat full equivalent. But it is thought by those geologists who are putting the Iowan in a separate and

[4] See table on page 292.

later glacial stage than the Illinoian that this concentrate was formed in a very short time, largely by wind action. As matters now stand, there seems need to determine whether or not this concentrate was formed in a short time. The mere declaration that it was formed rapidly is not to be taken as decisive, even if several geologists unite in the declaration.

The present writer is also skeptical of an interpretation which restricts the glaciation of one stage to the eastern part of the continent and of a succeeding stage to the central part of the continent, for in the Nebraskan, Kansan and Wisconsin stages there was glaciation over both the eastern and the central part. It thus seems more natural for the Illinoian of the eastern part to have its equivalent in the Iowan of the central part.

In the above estimates it was calculated that if the third or Illinoian glaciation covered only the eastern part of the continent it may have lasted only about 50,000 years, or from 210,000 down to 160,000 years ago. But if it covered the central as well as eastern part of the continent and embraced the Iowan it is likely to have lasted 75,000 years, or down to 135,000 years ago.

Summing up the matter of the relative proportion of time involved in the Pleistocene glacial and interglacial stages, it appears that fully 75 per cent. of the last 200,000 years has been under glacial conditions, but that prior to this the interglacial conditions were prevalent for at least 75 per cent. of the time. If then the entire Pleistocene period embraces a million years, the glacial conditions were prevalent for about 300,000 years, and the interglacial conditions for about 700,000 years, of which some 50,000 years, falling in the Sangamon and Peorian intervals, may not have been as warm as the present.

FRANK LEVERETT

ANN ARBOR, MICHIGAN

THE OXYGEN CONSUMPTION OF NERVE DURING ACTIVITY

THE recent article in this journal by Professor Winterstein[1] dealing with the above question has just come to my attention. The increase in oxygen consumption, over its resting value, of a nerve, stimulated by induction shocks, has been regularly interpreted as measuring the active metabolism of conduction. Winterstein presents reasons for considering this excess oxygen as the result largely or entirely of a local response to an artificial stimulus, and therefore unrelated to the normal events of conduction. Some of the points he makes are as follows. (1) When the region of the nerve actually stimulated is in the respiration chamber, the resting oxygen consumption is increased up to 400 per cent.; but when the excited region is excluded and the conducting trunk studied only a 14 per cent. increase or, in his own experiments, no increase is observed. (2) The extra oxygen consumption of the frog's spinal cord is much greater on direct electrical stimulation than when excited *via* a nerve—even when strychnized. (3) After stimulation of a dog-fish spinal cord no longer evoked muscular responses an excess oxygen consumption was still to be obtained. (4) The oxygen consumption of a snake's vagus nerve was not changed when the central and peripheral connections were severed, although normal spontaneously passing impulses were abolished.

It may not be amiss to point out here some possible answers to these points other than that suggested by Winterstein, as well as to indicate some of the important evidence that can not, apparently, be reconciled with his view. (1) It seems unwise to express the oxygen consumption of activity as a percentage of the resting, since much evidence indicates that the variables are independent. The resting metabolism is largely a carbohydrate oxidation or glycolysis, the active surely not. The former depends on nerve fibers, sheath, connective tissue, etc., while the latter is presumably limited to the axones themselves; and these structural elements vary widely from species to species. As a matter of fact, for dog-fish lateral line nerve the percentage increase in respiration on activity as determined by Parker, stimulating outside the experimental chamber, and Fenn, stimulating within, was almost identical. For the American green frog, Parker found a 14 per cent. increase; Fenn a 26 per cent. increase, and I (1930),[2] also stimulating within the chamber, a 35 per cent. increase. For the European frog I found for continuous stimulation a 100 per cent., for intermittent stimulation a 300–400 per cent. increase. The absolute increase in all cases, allowing for temperature, etc., was roughly the same —the values obtained when the stimulus occurred inside the chamber were *not* higher than when it was excluded.

(2) It is doubtful if even on direct electrical stimulation of the spinal cord all nerve cells are activated, and also glia and other cells may be stimulated or injured. The increased oxygen consumption is determined by the sum of all. Stimulation of an afferent nerve not only will fail to affect non-nervous tissues, but also there is ample evidence that, even after strychnine, such afferent impulses will not reach all cells and of those reached not all will be excited—some are actually inhibited. The reflexly evoked

[1] H. Winterstein, SCIENCE, 71: 641, 1930.

[2] R. W. Gerard, *Proc. Soc. Exp. Biol. and Med.*, 27: 1052, 1930.

activity could hardly equal the effects produced by passing a current through the cord itself.

(3) Similarly with the dog-fish cord. Absence of external response does not guarantee absence of conduction and responses all through the cord itself. There is another point in connection with (2) and (3) that will be returned to.

(4) The number of fiber-impulses normally passing along a vagus nerve is unknown, but compared with those evoked by tetanization with maximal stimuli is probably insignificant. The impulses continuously passing to skeletal muscle to maintain tone are, as judged by tension, less than 1 per cent. of the maximum motor impulses possible (neglecting afferent fibers). The elimination of such an amount of activity in the vagus could not be detected.

In favor of the accepted view of the functional significance of the extra oxygen consumption of activity may be mentioned the following: (a) The extra oxygen consumption agrees quite well with the extra heat production of frog nerve—although in heat measurements the region stimulated is several centimeters removed from that observed, and also the observed heat production is abolished when the nerve is blocked between the region stimulated and that lying on the thermopile. (b) Extra heat production and respiration last 10 to 30 minutes after all stimulation has ceased. (c) During equilibration, and in other conditions, the extra heat production, oxygen consumption and action potentials vary concomitantly. (d) These same changes reach a maximum with increasing stimulus strength and then do not further increase until much stronger shocks are used. This is true for oxygen consumption when the stimulus is applied within the chamber, *i.e.,* oxygen consumption does not parallel shock strength.

A control experiment to fully test the stimulus effect was reported in my initial paper (1927)[3] on this subject, and has recently been repeated by Mr. Chang, working with me. Two sets of nerves of the same frogs are mounted in the usual way on the electrodes of the two chambers of a differential manometer. On one side, the nerve trunks are cut a few millimeters from the electrodes, leaving the ends in place. On this side, then, the effect of stimulation with very little conduction is obtained, on the other stimulation plus full conduction. In two trials the increased oxygen consumption on stimulation with maximal shocks was 50 times greater on the intact side than on the cut one.

A final word on the effects of stimulation. Conduction involves, of course, successive stimulation of regions along the nerve. A stimulus, in order to just initiate this reaction, need only reach a threshold value over a microscopic region. As an electric current is increased in strength it spreads over a larger region and is able to cause excitation over this region, aside from conduction. When still more intense, electrolysis effects must begin to become serious and many secondary oxidations ensue. It must certainly be possible with strong electrical stimuli to obtain an increased oxygen consumption quite independently of the physiological response of the tissue. But with just adequate stimuli the local effect would seem, from the evidence presented, to be negligible. Professor Winterstein's failure to detect an increased oxygen consumption during activity when the stimulation took place outside the chamber must be explained, I believe, by injury to the nerve or inadequate sensitivity of the apparatus.

R. W. GERARD

WOODS HOLE

[3] R. W. Gerard, *Am. Journ. Physiol.,* 82: 381, 1927.

SETIGEROUS CYSTS IN THE EARTHWORM

IN the course of the routine dissection in the laboratory of Lumbricus, a very curious abnormality was discovered which was quite new to the laboratory staff and whose significance is not yet evident. This note is made in order to call it to the attention of others who may have observed it or who may be able to enlighten the author.

In the posterior portion of the specimen, which was of large size, obtained through the General Biological Supply House, in the segments from the eighth to the twenty-second from the posterior extremity, at least thirty-four conspicuous cysts were discovered. They were of oval form and of dirty, yellowish brown to dark purplish brown color and seemed to be lying loose in the coelom. Under ordinary low power there was no evident broken edge to indicate an attachment to the body wall, and some of the cysts dropped out simply on inverting the split end of the worm under water. In some segments as many as three cysts occurred.

Upon teasing the cysts with dissecting needles, it was found that they contained large numbers of setae of varying sizes. Some of the setae were nearly 1.5 mm in length, others only about .5 mm. Upwards of forty setae occurred in a single cyst. In one large cyst, the setae lay for the most part closely packed together approximately parallel to the long axis of the cyst. In most cases the setae were perfectly normal in form and appearance, but occasionally the chitin appeared to be irregularly split and fissured. This may have been an artifact. Besides the setae, in many of the cysts there were numerous nematodes of undetermined species. Usually there were as many as a dozen in a single cyst. Besides the adult worms

there were also found bodies which looked like embryos.

The material of which the cysts were composed was rather scanty. Teasing revealed only a coarsely granular material the cellular nature of which could not be clearly distinguished. The granules were of irregular size and of varying degrees of transparency. Some appeared quite black, others were brownish or colorless.

The setigerous sacs seemed to be normal in the segments in which the cysts occurred, and in many of the segments the nephridia seemed to be perfectly normal.

No one of the laboratory staff had ever encountered these cysts, and it is difficult to see what they mean. Do the setae in the cysts represent a response to the presence of the parasites? Do they represent bits of the setigerous glands which have "run wild" like tumors?

C. P. PHOEBUS

LAFAYETTE COLLEGE

AUTO-TRANSPLANTED GASTRIC POUCH FUNCTIONING FOR FIVE YEARS

THIS note is to record the interesting fact that an auto-transplanted pouch of the fundic portion of the stomach functioned for five years. The pouch was transplanted beneath the mammary gland in a female dog in January, 1925. The fact that the pouch secreted following the ingestion of a meal was recorded by Ivy and Farrell[1] in November, 1925, the animal being demonstrated in Cleveland at the meetings of the American Physiological Society[2] in December, 1925. This fact proved the existence of a humoral mechanism for gastric secretion. Observations on the motility of the pouch have been recorded,[2] the most important observations being that when the stomach proper manifested "hunger contractions" the pouch also manifested "hunger contractions," and that the ingestion of food not only inhibited the hunger contractions of the stomach, but also those of the pouch, which demonstrated that a humoral mechanism plays a rôle in the causation of the hunger motility of the stomach. These observations have been repeated and confirmed at intervals on this particular dog for five years. The secretory and motor functions of the pouch continued until the animal contracted an infectious jaundice and pancreatitis which resulted in death in June, 1930. A histological study of the pouch immediately after death revealed the same partially atrophic changes recorded in a previous article.[1]

A. C. IVY

NORTHWESTERN UNIVERSITY MEDICAL SCHOOL

[1] *Am. J. Physiol.*, Volume 74, 1925.
[2] *Am. J. Physiol.*, Volume 76, 1926.

SCIENTIFIC BOOKS

Astronomy. By R. H. BAKER. xix + 521 pp. Van Nostrand Company, 1930.

A TEXT-BOOK for introductory college courses in astronomy. The author, who is professor of astronomy at the University of Illinois, has purposely eliminated mathematics where practicable, and does not presuppose any considerable knowledge of physics. With these limitations the author has succeeded remarkably well in giving a picture of the science at the present day.

This book was needed. Many good text-books on astronomy have recently appeared. Yet some of them are too easy for a course of three hours a week during a whole year, and some are too difficult. Professor Baker's book is just what one requires for such a course.

In some respects his desire to avoid mathematical treatment may have been too great. The sections which deal with solar and lunar eclipses, for instance, do not contain any algebraical formulae at all. But in order to explain the phenomena some recourse to "algebra in words" was necessary. Would not even mathematically ill-equipped students prefer some simple formulae?

The book is beautifully printed. The illustrations are well chosen and well reproduced. Figures 10.25, 10.25A on p. 418 are obviously misplaced. One wonders what these pictures of constellations have to do with "the importance of radiation pressure," the subject of the corresponding section.

Some misstatements occur in the section on the variation in the speed of the earth's rotation (p. 52). It is stated that meridian transits of *stars* exhibit fluctuations due to irregularities in the earth's rotation. This is obviously confusing, as they are just the readings on the earth-clock. We further read: "From 1660 to 1790 the earth ran fast; then it ran slow until 1898 when it became fast again." Fast and slow should be interchanged. There is an amusing misprint in the preceding sentence: ". . . sudden changes in the period of rotation, at times as much as $0.^s00$ . . . [occur]."

Concluding the section on tides in the solid earth (p. 173), the author states, erroneously of course,

that the earth tides keep in step with the fluid tides of the ocean.

A few more remarks of this kind could be added. But they are in general of minor importance and can be made of every book in which such a wealth of new material has been digested. In fact, the book is exceedingly accurate. The definitions are very carefully chosen, and even where others have usually gone wrong, the book gives correct statements. Typographical errors are also very rare.

Astronomical instruments are briefly treated. Sextant, theodolite, zenith telescope, heliometer are not even mentioned. Apparently the author chooses to emphasize results more than methods of research.

The book is well up-to-date. Pluto, discovered so recently at the Lowell Observatory, is incorporated as the ninth principal planet. Justice is done to the importance of astrophysical research by devoting an admirable 40-page chapter to the constitution of the stars. In this chapter we find a very clear picture of what very recent developments have contributed to our knowledge of the make-up of stars. The following two chapters on the galactic system and exterior galaxies are also up to the minute.

An unusual subject in a book on astronomy is the earth's atmosphere, to which some considerable attention is paid, in particular to illustrate analogies with the sun and the planets.

The author has all sorts of illustrations at his disposal to make facts of exact nature clearly understood: "Everywhere in its interior the intensely hot star is kept inflated like a tire but with far less immediate danger for a blow-out or collapse" (p. 415) is but one example. He uses such parallels with all the freedom that has become common in scientific papers nowadays. But one never gets the impression that he has sacrificed any of the dignity of the science.

References to later sections are frequent throughout the book. For this reason it can not be easy reading for the general public whose knowledge of astronomy is meager. It does not, however, diminish its merits as a text-book for class use, or as a reference book. These merits are considerable. The book easily deserves a prominent place among the several good text-books that have recently appeared.

DIRK BROUWER

YALE UNIVERSITY OBSERVATORY

REPORTS

THE LÜBECK DISASTER[1]

OF the children inoculated in Lübeck with the BCG vaccine, more than fifty have died. Unfortunately, according to medical opinion, further deaths are to be expected, as the disease covers a period of from one to two months and the vaccinations were carried out at different times. The federal ministry of the interior has just published a statement based on the results of the inquiry as far as it has progressed. The statement throws a new light on the events in Lübeck and shows with what energy all persons in authority are working to clear up the matter. The statement of the federal ministry of the interior is expressed in precise terms and reads thus:

As was unfortunately to be expected, the terrible disaster that overtook the population of Lübeck in connection with the treatment to establish in children immunity to tuberculosis has not proved to be a catastrophe of only short duration but a calamity involving a series of fatalities and protracted illnesses the end of which is not yet definitely in sight. It is easily intelligible that the excitement over the sad event does not die down at once and that at home and abroad the demand for a more complete explanation of the disaster continues to persist. From the tone of the statements made by the federal minister of the interior, May 21, at the session of the head committee, and, June 16, at the plenary session of the reichstag, it was plainly evident that the investigations of the matter had been begun promptly and that they would be prosecuted without sparing any person or the prestige of any scientific method. Since, however, in some quarters suspicions to the contrary found expression, attention must be called to the fact that the scientific side of this affair involves some of the most difficult problems of bacteriology. The Federal Health Bureau was entrusted by the Federal Ministry of the Interior with the prosecution of the scientific investigations. The definitive outcome of the inquiry can not be announced before three to four weeks.

So far as it is possible to form an opinion from the investigations to date carried on by Professor Dr. Ludwig Lange, who was entrusted with this end of the research, it may be stated that the Calmette culture supplied by the Pasteur Institute in Paris was above reproach, but that it became contaminated during the process of recultivation in Lübeck. It is not open to question but that the Federal Health Bureau is using all available scientific means in the investigations that are being carried on to throw light on the complicated problem—investigations that are planned on a wide scale and will require the use of 600 or more experi-

[1] Berlin correspondent of the *Journal* of the American Medical Association.

mental animals. The frequently expressed wish that the course of the investigation might be expedited can not, however, be complied with, since biologic processes are involved in which any such attempts to influence matters are out of the question.

Separate from the question devolving on the Federal Health Bureau whether or not the Calmette prophylactic material as such was capable of producing the severe tuberculous infections in the infants instead of protecting them against the disease must be considered the question whether or not everything was done in Lübeck to carry out in a manner above reproach the Calmette prophylactic treatment, after it was once decided to employ it. The investigation of the manner in which the vaccine was employed is primarily the duty of the state of Lübeck. In the course of the investigations, a series of incriminatory charges developed, as was foreshadowed in the report of the referee sent to Lübeck by the Federal Ministry of the Interior, May 22. In this connection, the following points merit consideration.

1. After the federal ministry of the interior, in 1927, in the matter of protective treatment against tuberculosis by means of living bacilli, in agreement with the conclusions reached by the federal health council, had recommended a conservative policy, it would have been proper if the Lübeck centers concerned, before instituting the vaccine treatment, had inquired whether or not the federal ministry of the interior, in spite of many favorable reports from foreign countries, still preserved its waiting attitude.

2. After the original culture secured from the Pasteur Institute had been recultivated for nearly nine months in the Lübeck laboratory on various cultivating mediums, it would have been wiser, before the first application of the protective material to infants, to test its potency by animal experimentation. That was not done.

3. The surveillance of the children who were inoculated with the vaccine was not adequate.

4. The destruction by Professor Deycke, April 26 (that is, after the harmfulness of the protective material had become known), of the supply of vaccine left in his hands must be regarded as of questionable indication, irrespective of the motives that induced the act. Professor Deycke's action did not, however, militate against the clearing up of the affair, since the Federal Health Bureau was able to secure possession of entirely sufficient remnants of the protective material employed. The Federal Health Bureau was able to obtain all other research material needed.

5. It can not be justified that, after the forenoon of April 26, when the harmfulness of the protective vaccine employed had been proved by the necropsy on one of the infants who had died, several doses of the vaccine were allowed to remain in the hands of midwives. Fortunately, this remaining vaccine was not administered to any new subjects but only to such infants as, before April 26, had already received the first inoculation, which was probably decisive as regards the transmission of the infection.

6. It is subject to censure that the persons who were responsible for the application of the protective vaccine, among whom there seems, too, to have been a lack of cooperation, did not inform until a late date the center in Lübeck having first jurisdiction in such matters, of the damage that had been done. The *Reichsmedizinalverwaltung* (federal administration of medical matters) was not informed of the events until May 14.

To what extent the charges, or censures, mentioned (which do not essay to pass a judgment on the scientific merits of the Calmette procedure) should or may be considered in determining the matter of culpability, will be established by the criminal procedure, which has already been instituted.

SCIENTIFIC APPARATUS AND LABORATORY METHODS

INTRA VITAM TECHNIQUE FOR THE STUDY OF THE LIVING CELLS OF INSECTS

THE method of studying living germ cells as practiced by Lewis and Robertson,[1] Strangeways and Canti,[2] Bělăr[3] and others shows certain lacks and deficiencies. These are evidenced by the appearance of pseudopodia, fused cells and nuclei and other abnormalities. Such irregularities do not appear in well-fixed material and we do not believe that they are a part of the behavior of germ cells in normal conditions of development.

We have been able to develop a technique for insect germ cells in which such abnormalities do not appear, due to the fact that the body pressure (follicular and cystic) and specific ferments are not disturbed. Neighboring cells are not separated from each other or from the surrounding tissues. Hence no fusion of spermatocytes or spermatids occurs, nor do

[1] M. R. Lewis and W. R. B. Robertson, (II) "The Mitochondria, etc., in Chorthippus," *Biol. Bull.*, 1916.

[2] T. S. T. Strangeways and R. G. Canti, "The Living Cells in Vitro as Shown by Dark Ground Illumination and the Changes Induced in Such Cells by Fixing Reagents," *Quart. Jour. Micr. Sci.*, 71, 1927.

[3] K. Bělăr, "Beiträge zur Kausalanalyse der Mitose. II. Untersuchungen an den Spermatocyten von *Chorthippus lineatus*," *Arch. Entw. Mech.*, 118, 1929.

pseudopodia ever appear, such as all workers, using the tissue culture methods, report.

We are calling this the intra vitam method in contradistinction to the earlier in vitro method. We feel confident that it has some merits over the older ones. Because it is simple and practical we are publishing the method before the longer paper, giving the details of our observations as well as the photomicrographs and drawings, is completed. It is so easy to use that we shall employ it in the future as a part of the laboratory work in cytology.

Technique

A male grasshopper of suitable age is anesthetized for several seconds. As soon as the ether has taken effect, the hind legs are severed at the autonomous joint. The wings are cut off behind the pronotum, and a rectangular opening, about 2 mm by 1 mm, is cut through the chitinous wall of the second, third and fourth abdominal segments, just left of the mid-dorsal line. The insect is then placed on its right side, parallel to the width of a sterile glass slide, to which it is firmly attached by means of melted paraffin. The paraffin is drawn into a pipette and is then carefully dropped onto the forelegs and antennae of the grasshopper. The paraffin is run around the head of the insect and along the ventral side of the body, which faces the right-hand side of the glass slide. A narrow ribbon of paraffin is continued around the last abdominal segment and on out toward the left side of the slide for about 15 mm. Next, the paraffin is led up and back to the anterior end of the grasshopper (see figure). These three paraffin walls, approximately 15 mm by 10 mm, together with the body of the grasshopper and the enclosed surface of the medium (Bělâr, '29), convert this basin into a nutrient lake. A hot needle applied to the outer rim of the paraffin wall insures close adherence to the glass slide and prevents leaking.

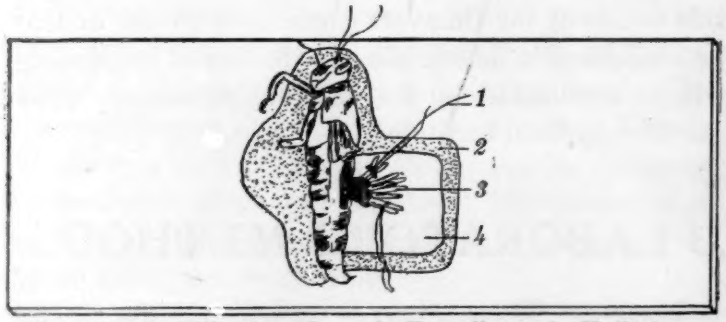

Fig. 1. 1. Silk threads. 2. Paraffin. 3. Follicles. 4. Lake of medium.

Care must be taken, when affixing the grasshopper to the slide, that the spiracles in the abdominal wall are not flooded with paraffin. The anal aperture is also left free so that normal evacuation can take place in preparations which are to be maintained for several hours.

Before the grasshopper recovers from the effects of the anesthesia, the testes are drawn out through the aperture in the abdominal wall. The yellowish connective tissue membrane, which encloses the tightly packed follicles, is carefully torn away with a sharpened needle point and the follicles float out into the lake of medium. They remain attached, of course, at the proximal end, to the vasa efferentia. Several of the upper ones, as well as two or three of the lower follicles, are secured with a loop of silk thread. The loop is drawn tight and firmly fastened to the wall of paraffin with a drop of melted wax. This attachment of some of the free follicles prevents the withdrawal of the testes into the body cavity and it lessens the movement of the intervening follicles.

The eight or ten free follicles, exposed along nearly their entire length, may be studied for hours, at intervals or continuously. In time the culture medium evaporates slightly and must be renewed. It is best to draw off the used medium and fill the lake with fresh fluid.

Observations Under the Microscope

Some of the interesting things that we have observed with the 16 mm objective are the tridimensional or tubular nature of the follicle; the shape of the cysts with their walls; the variations in the shape of the cysts. These increase greatly in size and the walls thicken as they grow. In the spermatid region the cysts elongate greatly, the conical structure reaching down toward the center and proximal end of the follicle. The stages of germ cell development can also be recognized and their place of occurrence in the follicles fixed. The bundle of sperms in the grasshopper as they move and turn (Landrum, work unpublished) can be followed. The turning of the sperm in the crickets (Baumgartner, work unpublished) can be recognized.

With a 1/12 water immersion objective and good illumination (a bright substage lamp) practically every structure previously described in fixed material may be studied without the aid of intravital staining.

The walls of the follicles are thick and most probably muscular. Cysts of spermatogonia are readily distinguished from spermatocytes by their locus, size and cellular inclusions. Spermatocytes go through the various stages of cell division while under observation. Spermatogonia also divide. Chromosomes can be watched as they migrate from the equatorial plate to the poles. Here a very small refractive spherical centrosome is visible. Astral rays may be seen radiating from this point or body. Numerous threads of mitochondria are distributed to the daugh-

ter cells and form the nebenkern. Telokinetic movements can be followed. The young spermatid cells have short axial filaments. These can be seen to elongate and become the tails of the more mature spermatids. The long tails can be traced from the heads down toward the open end of the follicle. The tails are in groups and are more or less intertwined. The aggregation of the sperm into bundles can be studied, as well as the movement of the bundle to the open end of the follicle.

Preparations of crickets and beetles have been set up, with slight modifications of the technique. It is best to mount a cricket with the back flat on the slide. The follicles are shorter and the cells are smaller, but they may be studied by using the above-described method.

We have been able in a few months to see most of the characteristic structures and to follow many of the activities of the *living* germ cell, in a state that very nearly approaches the normal condition. We anticipate that our continued efforts will bring out other important data. It may not be too optimistic a viewpoint to expect the solution of some knotty problems in chromosome behavior and spermatid transformation by the use of this method. With such a hope we are offering the details of the method to other investigators.

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A RAPID POSITIVE CONTROL METHOD OF HANDLING SMALL QUANTITIES OF LIQUIDS

FOR a certain experiment here there was needed a means of adding small quantities of liquids that would make it possible to secure more positive and satisfactory control than is afforded by any ordinary pipette or burette. The final design of the special tube or pipette for this purpose is shown in Fig. 1. As is at once apparent, the pipette substitutes a mercury plunger or piston for the usual rubber bulb or the rubber tube connected with the mouth. By inclining the pipette at an angle such as indicated and rotating it until the mercury has filled bulb N the air on the N side is crowded out at the tip. If now the tube, still at the same angle, is inserted into the liquid supply and rotated about its own axis until the mercury runs from N into the bulb M the liquid will be drawn up into the pipette to a height depending on both the angle of inclination and the amount of rotation, each of these conditions being subject to definite control individually. Scratches on the tube corresponding to volumes desired for particular work make the tube suitable for quantitative work. To expel any quan-

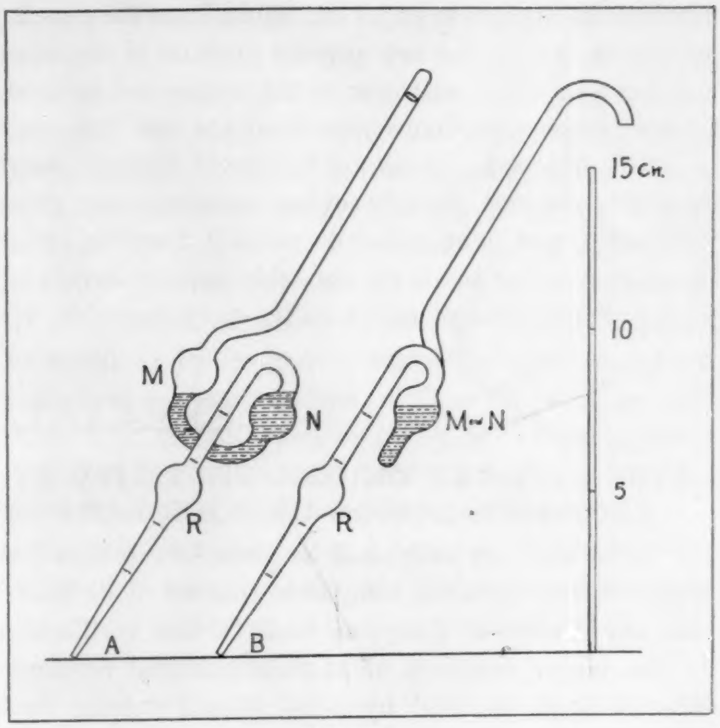

FIG. 1

tity of the liquid from one drop to the entire quantity contained one has but to rotate the pipette in the reverse direction, the mercury flowing back into N and crowding out the liquid to an extent positively controlled by either the inclination or the rotation, or both.

Compared to a burette in handling small quantities of liquids it is much more quickly filled and emptied and involves none of the uncertainties of either a stopcock or a pinch-cock. It is superior to any type of pipette operated by suction from the mouth, directly or through a short length of rubber tubing, for it eliminates any chance of fumes or liquids being inadvertently drawn into the mouth, as well as all danger of mouth or breath moisture contaminating the pipette, and relieves the user of the rather unpleasant and often inconvenient, if not unsanitary, use of his mouth.

On many grounds it is to be preferred to a pipette using a rubber bulb, particularly where definite quantities are required. When using a rubber bulb one is never sure just how much it should be squeezed in order to get the precise quantity needed—if too little, one has to begin over; if too much, one has to remove it from the liquid before it is fully distended and then allow air to bubble through the liquid, spraying the same into the bulb, or else must maintain the pressure on the bulb just so until the liquid is ejected. Rubber bulbs become contaminated and the contamination is invisible. They are flabby, often leaky, and offer uncertain control of the position of the tip of the pipette, in contrast with the rigidity of the new type. In using ordinary pipettes the heat of the hand is likely in the case of volatile liquids to cause a vapor

pressure so high as to expel the liquid from the pipette prematurely. In the new pipette the heat of the hand can have no effect whatever as the upper end is open. It is obvious, also, that a pipette of the new type may be easily cleaned. It should be stated that the bend at the upper end, though neither necessary nor given originally, was later added to make it possible either to hang it up or lay it on the table without involving any contamination of either its tip or of the table, for the bent portion is just long enough to make the tip incline downward, but not long enough to cause it to touch the table.

Inasmuch as pipettes of this new type have already found a place in three departments here it is thought to be of sufficient general use to justify passing the idea on to others.

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SPECIAL ARTICLES

EXCESSIVE TAX ON SOIL FERTILITY BY CROP PRODUCTION ON POOR LAND

"Unto him that hath shall be given—from him that hath not shall be taken away even that which he hath." The above verse of Scripture finds further verification in the larger amounts of certain essential nutrients exacted from the soil by some plants, among them such important cereals as wheat and barley, per unit weight of mature crop grown on poor land than if grown on rich soil. That a soil markedly deficient in available phosphorus or nitrogen must supply more of these elements for the production of a unit weight of wheat or barley grain than is required from a soil fairly rich but not oversupplied with these elements lies in the relationship which the supply and absorption of given quantities of essential elements at various growth periods of the plant have to yield.

It appears from the standpoint of plant nutrition that the conditions which determine crop production can be reduced to three general considerations or factors. They are: (1) the minimum requirement (quantity) of each essential element needed to produce a unit quantity (weight) of mature plant and of its differentiated products, for example, in cereals —grain, straw and roots; (2) the time required for the soil (or other growth medium) to supply given amounts of each essential element and for it to be absorbed by the plant at given growth stages; (3) the length of time required for a given quantity of each essential element after it is absorbed to function to completion in the processes for which it is required and to attain the minimum percentage in the mature plant product of which it becomes a part.

The values of each of these three factors are different with the elements concerned. For example, the amount of phosphorus required to produce a given quantity of wheat grain is different (smaller) than that of nitrogen. The time required for a soil to provide a given unit quantity of available phosphorus to wheat plants is much longer (except in rare cases) than that required for nitrogen. The time required for a unit quantity of phosphorus, after it is absorbed by the wheat plants, to function to completion, that is, for the plant to increase in weight until the quantity becomes the limiting factor to growth, is much longer than that for nitrogen. The values of each of the above three factors are different among plant species; they also vary among varieties of any given species.

The time required for a poor soil to supply plants, for instance, wheat, with a given quantity of a given plant food—phosphorus, for instance—is different (longer) than it is in the case of a soil that is fertile as to this element. This difference projects the time when equal quantities are absorbed by plants grown on such different soils much later in the growth development of the plants grown on the poor soil than in the case of those grown on a rich soil. But as the total growth period of many plants is largely fixed by their genetic constitution—although the actual growth period varies more or less with soils and climatic conditions—it follows that the developmental stage obtained when equal quantities of an element are absorbed by plants grown on such different soils would be much nearer to the period of maturation for those grown on poor soils than those grown on the rich soils. As a specified yield requires a quantity of each essential element, which can not be less than that indicated by the product of the weight of the mature plant times the minimum percentage of such element in the product, it follows that the time required for a plant to absorb that quantity when grown on a poor soil would much more restrict the time remaining for utilization of that material than would be the case if the plant was grown on a rich soil.

The maximum utilization, or growth, or increase in weight—whatever term is desired to express the phenomenon of the additions to the weight of a plant by the absorption of elements subsequently to the time a specified quantity of a given element was contained in the plant—is obtained when the given specified quantity enters the rôle of a limiting factor. The element attains its minimum percentage when the maximum amount of other elements have been combined with it,

or have otherwise been incorporated into the plant. As a time interval was required for the given quantity to be absorbed, so a time interval will be required for other elements to combine with it or become a part of the plant. But the quantity of other elements that will be added to the weight of the growing plant subsequent to the time the specific quantity of the given element is absorbed is conditioned by similar factors as those which affected the intake of the specified quantity in question—namely, the character of the soil and the climate together with that of the time available for the processes to proceed.

The genetic constitution of the organism brings on the termination of growth in due time regardless of how favorable other conditions may be. If one plant process is contingent on another and both stand together reciprocally in their relation to the whole organism, variation in one must have a corresponding reaction in the other. It is the contingent and in a measure reciprocal relation of the two processes—(*a*) the time required for a plant to absorb a given quantity of an element, (*b*) the time required wholly to utilize the quantity absorbed—that sets the condition whereby a soil deficient in an essential element like phosphorus is required to supply a larger amount of this element per unit weight of mature plant than is required from a soil well supplied with this element. That is, the longer the time required for the plant to absorb a given quantity, the shorter the time remaining for it to utilize it. If the quantity absorbed is too large or the time required to absorb any given quantity is too long in relation to the time required for complete utilization, the result of such a condition is that a higher percentage of the element will be found in various parts of the mature plant. The yield (weight) of plant that was obtained would also have been obtained by a smaller quantity of the element if absorbed at an earlier growth stage.

The relation of yield to the composition of a crop such as wheat or barley grown on poor soil as compared to that grown on a fertile soil has similarity to the relation between yield and composition expressed in the "Mitscherlich law" but obtained under diametrically different conditions. The relation cited in the latter case ("Mitscherlich law") of decreasing increments of yield with increasing increments of factor (the element deficient in the poor soil) supplied and absorbed by the plant is due to the fact that the time required for such increasing amounts to be absorbed projects the period when this is attained correspondingly closer to the period of maturation, and the time thus remaining for growth after the quantity is absorbed is too short to permit of its complete utilization—hence the high percentage of the element in various parts of the plant. The relatively high percentage of the element in the crop grown on a poor soil is due to the fact that the soil could not supply sufficient amount of the element in the early growth stage of the plant to effect the requisite vegetative development required for a large crop, and the largest part of the quantity which the plant did contain at the end of growth was absorbed too late to be effective. Cause for the relatively high percentage of phosphorus or nitrogen that is frequently found in wheat or barley grown under the conditions mentioned—a soil poor in one of these elements as compared with the soil fertilized with one of the elements—is thus due to the same factor: insufficient time for utilization after the given quantity is absorbed.

The relations above stated, however, do not hold for plants that are markedly less differentiated than are wheat and barley as to the requirements of the final products—grain, straw, roots.

A more complete account of the experiments will appear elsewhere.

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COMPARATIVE RACIAL DIFFERENCES IN COLOR-BLINDNESS[1]

Congenital color-blindness occurs in three chief forms: the common form in which there is confusion between red and green; a rare form known as total color-blindness in which all colors are confused, and a very rare type in which blue is confused with yellow. Red-green blindness appears to be a sex-linked Mendelian character and occurs much more frequently in males than in females.

Interest in possible racial differences in congenital forms of color-blindness was first aroused by Gladstone in 1858, and much scattered work on the subject has been done since that time. Holmgren's wool test has been used most extensively, but this test as well as all those dependent on matching pigment hues is unsatisfactory. Recent work has shown that the wools probably detect only about half of the cases of true color-blindness. Of late years, tests have been made using figures on pseudo-isochromatic cards. Most of these tests consist of a series of plates on which a colored number is presented against a colored background, the diagnosis being made by the manner in which the subject reads the numbers. The best-known tests of this type are those of Stilling and Ishihara. Von Planta[2] compared results obtained by

[1] More complete details of this work together with a summary and comparison of studies by earlier investigators will appear in an early article.

[2] P. von Planta, "Die Häufigkeit der angeborenen Farbensinnstörungen bei Knaben und Mädchen und ihre Feststellung durch die üblichen klinischen Proben," *Graefe's Archiv für Ophthalmologie*, 120: 253–281, 1928.

several of these tests with those given by the anomaloscope and concluded that the series devised by Ishihara was the most satisfactory.

I recently used this test to investigate the incidence of color-blindness among American Indians of the Southwest as well as in a group of Negroes in New Haven. The results obtained are set forth below in comparison with those published on Europeans by von Planta[2] in Germany, and on white Americans by Miles[3] at Stanford University and Haupt[4] at Baltimore. The figures in the table are based on the Ishihara test and refer only to males.

COMPARATIVE TABLE

Race	Investigator	Number tested	Frequency of color-blindness	Percentage
White (Europeans and Americans)	von Planta	2,000	159	7.95
	Miles	1,286	106	8.2
	Haupt	448	35	7.8
American Indians	Clements	624	12	1.9
American Negroes	Clements	325	12	3.7

The percentages of color-blindness among the three widely separated groups of white males closely approximate each other. Taking the three groups together, the actual percentage of the defect among the 3,734 individuals tested amounts to 8.04 per cent. One case in Miles's group was totally color-blind, but all the rest were red-green blind.

Of the 624 Indian males tested, 392 were full bloods, among whom were found eight cases or 2.0 per cent. of red-green blindness. Of these eight cases, six qualified as completely green-blind according to the test while the other two were red-blind. Among the 232 mixed bloods, three cases or 1.2 per cent. of red-green blindness occurred. Two of these were completely green-blind and one was red-blind. In addition, one case of total color-blindness was discovered in the mixed blood group. This case exhibited concomitant symptoms of poor central vision, marked photophobia and nystagmus. A group of 202 Indian females was also tested, but no case of color-blindness was found.

Of the 323 Negro males tested, 205 were probably full bloods. Seven cases or 3.4 per cent. of red-green blindness appeared. Five of these cases were complete green-blinds and the other two were red-blind. Among the 118 obviously mixed blood Negroes were five cases or 4.2 per cent. of red-green blindness, four cases being green-blind and one red-blind.

Miles states that the proportion of green-blindness to red-blindness in the group he tested was approximately 3 to 1. This ratio holds for the group of von Planta where the percentage of green-blindness was 5.75 and that of red-blindness 2.2. In my own results, 2.7 per cent. of the Negroes were green-blind and 0.92 per cent. were red-blind. In the total group of Indians, 1.2 per cent. were green-blind while 0.48 showed red-blindness. Apparently the approximate proportion of 3 to 1 for these two types of color-blindness holds for each of the three racial groups.

The above results seem to indicate that racial differences in color-blindness do exist. In the case of the white groups, the nature of the sampling and the large number of individuals indicates that the incidence of the defect for white males may be rather confidently set at about 8 per cent. The Indian testees were drawn from several different tribes and probably constitute a fairly representative sample. While tests on a larger group might give an incidence somewhat different from that stated here, there can be little doubt that the frequency of color-blindness among Indians is much less than among Caucasians. The Negro sample is too small to do more than indicate the probability that the incidence of color-blindness among Negroes falls somewhere between that for Caucasians and Indians.

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[3] W. Miles, "One Hundred Cases of Color-blindness Detected with the Ishihara Test," *Journal of General Psychology*, 2: 535–543, 1929.

[4] Quoted by Miles, *op. cit.*, p. 538.

BOOKS RECEIVED

CAMP, CHARLES L. *A Study of the Phytosaurs.* Pp. x + 174. 6 plates. University of California Press. $3.50.

GREGG, WILLIS R. *Aeronautical Meteorology.* Second edition. Pp. xvi + 405. Ronald Press. $4.50.

KILBY, CLINTON M. *Laboratory Manual of Physics.* Pp. vii + 129. 75 figures. Van Nostrand. $1.75.

LEVERETT, FRANK. *The Pleistocene of Northern Kentucky.* Pp. xi + 403. Kentucky Geological Survey.

MELLOR, J. W. *Intermediate Inorganic Chemistry.* Pp. xx + 690. Illustrated. Longmans, Green. $3.00.

OSBORN, HENRY F. *Fifty-two Years of Research, Observation and Publication. 1877–1929.* Pp. xii + 160. Scribner's. $1.50.

PEARCE, LOUISE. *The Treatment of Human Trypanosomiasis with Tryparsamide.* Pp. 339. Rockefeller Institute. $2.00.

SOUTHWELL, T. *The Fauna of British India, including Ceylon and Burma.* Cestoda, Volume I. Pp. xxxi + 391. 221 figures. Taylor and Francis, London. 22/6d.

TROLAND, LEONARD T. *The Principles of Psychophysiology: A Survey of Modern Scientific Psychology.* Volume II: Sensation. Pp. xxi + 397. 97 figures. Van Nostrand. $4.00.